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AERIAL PHOTOGRAPHIC RECONNAISSANCE

SHORT HISTORICAL EXPLANATION, WS 117L
DISCOVERER, SENTRY AND MIDAS CHRONOLOGY
1946-1959 27 Sep 1959

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AERIAL PHOTOGRAPHIC RECONNAISSANCE

Introduction

During the summer of 1943, an era in aerial reconnaissance ended. The final group of Air Corps observers was being trained at Brooks Field, Texas, but these men ("The Eyes of the Air Corps" the sign arching over the main gate called them) were never to fly a photographic mission in combat except by sheer chance. While they were familiarizing themselves with the vagaries and vapors of the K-3B and K-20 cameras installed in lumbering and underpowered Curtiss O-52's, sleek stripped-down P-38's (F-5's) had already proved over North Africa that a pilot alone could bring back good quality combat photographs and maps and that the observer was an anachronism.

To be sure, bombers would continue to carry a few cameras (particularly to cover bomb drops), but these would be operated by regular crew members who were radio operators or gunners first and cameramen second.

The advent of high speed reconnaissance aircraft and of camera locations remote from the operator ushered in a whole series of new and complex design and operational concepts; the concepts themselves ushered in a whole series of new and very expensive aerial cameras.

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Higher and higher speeds meant that no longer could camera "windows" be mere holes in the aircraft fuselage. Aerodynamic considerations made the addition of glass ports a necessity, thus adding to the problem of light transmittance. The cameras and their accessories needed fully automatic control systems, since the pilot could not perform too many motions or calculations at the high speeds he had to fly.[1]

Moreover, when operational altitudes of 80,000 to 100,000 feet were forecast, intricate optical systems, stabilized mounts, and methods of maintaining constant temperature and pressure around the whole photographic installation became necessary. For example, lens cones had to be designed to compensate automatically for the effects of rare atmosphere on focus; and while camera mounts, vertically stabilized by gyroscopes, were capable in 1949 of maintaining cameras level to within 10 minutes of arc, better performance would be required of them. Ten minutes off vertical at 100,000 feet altitude represented a ground distance of some 300 feet.[2]

To be relatively safe from enemy interception, a photographic reconnaissance aircraft would be forced to fly either at very high altitudes (80,000, 100,000 feet and higher) or at very low altitudes. Within limits, very high altitude reconnaissance called for longer focal length cameras to provide photographs with acceptable detail. Very low altitude reconnaissance called for ever faster shutter speeds (which in turn called for wider aperture lenses with high light transmittance values), faster cycling rates,* and for synchronizing movement of the film with movement of the image across the focal plane (image motion compensation).[3]

By 1949, camera development costs had skyrocketed to levels unheard of during World War II. World War II cameras of 24-inch focal length cost about $20,000 to develop. Development cost of a postwar 48-inch camera jumped to $256,000. A 100-inch camera developed for use at 40,000 feet involved an outlay of $760,000. Altitudes of 100,000 feet implied camera development costs in the millions of dollars.[4]

In August 1955, the Air Research and Development Command issued a revised technical program planning document entitled "Photography." The document, together with an accompanying set of five technical requirements, substantially accelerated the entire Air Force photographic development program and set ambitious goals for the 1960-1965 period and beyond. The "ultimate" goal--to be attained with all possible speed--

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* A camera "cycle" is the time necessary to open and close the shutter for a single exposure and then to move the film into position for the next exposure.

was a reconnaissance subsystem capable of transmitting to earth from an unmanned satellite high acuity[*] photographs from which small details could be identified by examining the developed prints under a microscope.[5]

By-products of the satellite-oriented development program would be smaller, lighter, and simpler airborne camera systems of progressively higher resolution. Planners foresaw reconnaissance altitudes of 100,000 feet for day photography and 70,000 feet for night photography by 1960. In 1965, airborne photographic systems--by then immune to external environment--were to be operating at 500,000 feet. The satellite-borne system was to come into being as soon after 1965 as possible.[6]

The requirements were still far in advance of the state of the photographic art in 1955. Using 1955 components and techniques, a camera system capable of producing high resolution photographs from even 70,000 feet and in sufficient numbers to satisfy General Operational Requirement 92 (Very High Altitude Reconnaissance Weapon System), would need a focal length of seven feet, would produce negatives 12 feet square, and would require 50 times the film capacity of available magazines![7]

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[*] Photographic acuity is the ability of a camera system to resolve detail.

Cameras installed in 1955-vintage, 500- to 600-knot operational aircraft were capable of producing high quality black and white photographs at altitudes between 1,000 and 55,000 feet during clear daylight and up to 40,000 feet during clear night conditions. Above these altitudes, the bulk and weight of the camera equipment became prohibitive. Available cameras, equipped with automatic exposure controls, had focal lengths of from three inches to 20 feet and format sizes varying from five square inches to almost five square feet

Resolution theoretically obtainable was about 40 lines per millimeter, but because of vibrations and camera location, actual resolution was about 10 to 14 lines per millimeter. (The 1965 requirement for 500,000-foot photography was 100 lines per millimeter.) Image motion compensation was automatic up to 8,000 feet altitude; above 8,000 feet, altitude information had to be set manually into the camera control system.[8]

The planning document specifically emphasized that improved photography could no longer be expected through improvement of the camera alone. In the past, the installation of ever larger and heavier cameras had resulted in improved acuity and resolution as altitudes increased. The limiting point for this type of "improvement" had been reached, however. Supersonic aircraft, into which were crammed fantastic amounts of

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equipment and in which every cubic inch was at a premium, made necessary a photographic installation that was light and compact, and that had a frugal appetite indeed for either electrical or mechanical power.[9]

Needed improvements in airborne photographic equipment could be described, in general, under three principal headings: improvements in the camera; improvements in the installation; and insulation of the equipment from the operational environment.

What kind of reasonably-sized camera could be developed to fly a satisfactory reconnaissance mission from 100,000 feet altitude? Arbitrarily, a requirement might be set up for a 36-inch focal length camera capable of realizing at least 80 percent of its theoretical acuity while airborne. It might also be assumed that as of 30 June 1956 a camera of 36-inch focal length with an aerial resolving power of about 22 lines per millimeter could be built. Such a camera would be theoretically capable of resolving a five-foot cube from 100,000 feet altitude. Resolution, however, was not synonymous with identification. Was the cube a jeep, a storage shed, a large picnic table, or a light tank?

These questions could probably be answered if the resolving power were doubled--i.e., to 44 lines per millimeter. Since

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the camera would realize only 80 percent of its theoretical resolving power, however, its resolution would have to be raised to 55 lines per millimeter. This figure, being marginal, would have to be boosted to 60 lines per millimeter for safety.

Would a camera of such high resolution be feasible? During World War II, the Army Air Forces had one type of camera that occasionally (when photographic conditions were practically perfect) would resolve 40 lines per millimeter from 20,000 feet altitude. Improvements in camera components and in installation methods since that time seemed to indicate that a camera with a resolving power of 60 lines per millimeter could be designed and built.

In addition to increased acuity, increased reliability of cameras and components was necessary. Promising in this regard would be extensive testing of cameras and components to insure durability and environmental resistance, and simplification of camera design to make use of unitized or modular construction for easy replacement of defective parts.[10]

Improvements in camera installation consisted principally of the development of stabilized "torquer" mounts which not only held the camera in a predetermined position at all times but also isolated it from aircraft vibrations and flight movements. The mount itself, which eliminated mechanical gearing between the camera gimbals and the airframe, had been a unique development of Wright Field's Photographic Laboratory, and it enabled an airborne camera to realize about 80 percent of its inherent acuity.

Another installation improvement was the "duplexing" of cameras (i.e., the combination of two optical systems and of two separate film magazines in a single camera body), which made possible convergent photography with the use of a single mount and a single window. Duplexing not only saved space and weight, it simplified prevention of camera center of gravity shifts with advancing of the film, since film rolls could be arranged to work in opposite directions. Moreover, since the dual mechanisms within the camera body provided equal and opposite moments of inertia in operation, camera stabilization would be simplified.

The protection of airborne photographic equipment from environmental conditions of high speed, high altitude flight, without undue drain on the aircraft's power supply, was to be accomplished in the immediate future by providing a pressure-sealed capsule to contain the camera and mount, and by insulating the camera with a "blanket" of some kind. A capsule, whose interior remained at ground air pressure for the duration of a mission without requiring additional pressurization in flight, would avoid draining aircraft power vitally needed elsewhere, and would help insure good electrical operation of the camera, proper film positioning in the format area,* and maintaining proper focus during photographic runs.

Protection of cameras and mounts against excessive temperatures generated within the earth's atmosphere at speeds of Mach 2.0 and above meant some kind of insulating cover and possibly a supply of dry ice for positive cooling as well. For best focus, an aerial camera had to be kept at a stable temperature for several hours prior to picture taking. However, once the photography ceased, the camera temperature could be allowed to rise to the maximum safety limit of the film for the balance of the flight home. Other environmental problems of high speed flight had to do with maintaining laminar flow of air past the photographic window in the aircraft fuselage and the fabrication of the window itself from glass that would be optically stable at high temperature.[11]

The August 1955 planning document pointed out deficiencies that existed in a number of specialized types of airborne photographic equipment. Recording the strikes of modern weapons posed a substantial problem. While the Air Force called for the ability to record rocket and missile impacts at ranges of 30,000 feet within a 65-degree cone ahead of the aircraft, and to record bomb bursts either ahead or astern, the strike cameras of 1955 could photograph machine-gun and rocket impacts only to about 1,500 feet.

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* The best method of holding film flat during exposure is by use of a vacuum plate in the format area. At 100,000 feet, creation of a pressure differential between the front and rear surface of the film becomes impossible unless the camera compartment is pressurized.

The need for high-resolution radarscope recording cameras grew more urgent as fire control, bombing, navigation, and missile guidance systems multiplied and as airborne cathode ray tubes grew larger in size. With operational nuclear-powered aircraft looming on the Air Force horizon, development of radiation-resistant photographic systems also gained in importance.

Increasingly in evidence throughout the Air Force was a strong interest in airborne rapid-processing devices which could produce high resolution photographs within seconds after exposure. High speed movements of enemy ground forces in tactical situations made reduction in processing time imperative. Connected with the rapid processing devices would be either a television system by which the developed prints could be transmitted to receiving stations on the ground or ejection equipment by which the prints could be dropped to tactical commanders in the combat area.

The issuance of the August 1955 planning document also marked an attempt to coordinate and unify a photographic development program which, to that time, had emphasized hardware rather than the solution of known technical problems. The result of this emphasis had been a wide variety of photographic components of great similarity. While reconnaissance systems and techniques were, by their nature, more specialized than some other Air Force functional areas, and while no system could fit all jobs, there was still a great deal to be done in developing common items such as lenses, shutters, magazines, control and drive systems, and mounts that could be used in as many camera systems as possible. Standardization of photographic components would mean not only a considerable saving in money, but would also prevent the saturation of limited laboratory time and facilities with a multiplicity of similar projects and tasks.[12]

The acceleration of aerial photographic system development brought about a situation in which not only the cameras already installed in operational aircraft were obsolete, but in which the cameras slated to replace them were obsolete also. The projects reoriented and the tasks initiated in late 1955 and early 1956 to meet the requirements laid down in the planning document still, for the most part, had [redacted] contractors assigned to them by the end of June, but performance characteristics for the new family of advanced camera types had been clearly set forth. These characteristics were such that they would enable the Air Force to collect, in relative safety, accurate aerial photographs containing intelligence information of the highest quality and value.[13]

Daytime Area Reconnaissance from High Altitude

Daytime aerial photographic reconnaissance had three basic divisions: area reconnaissance from high altitude; specific target reconnaissance from high, medium, and low altitudes; and mapping reconnaissance from high and medium altitudes.* Area and specific target reconnaissance could be accomplished using cameras mounted either as verticals or obliques. The purpose of area reconnaissance was to provide information on the route to the target and on the target's surroundings, in order to aid in its identification from the air. Specific target reconnaissance provided detailed photographs of the immediate target area, from which vulnerable points could be located and target defenses assessed. Mapping photography produced extremely accurate charts of relatively large areas. These charts were indispensable for navigation and were a further aid to target identification.[14]

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* The terms "high," "medium," and "low" altitude were not easy to define. The principal difficulty was that "medium" altitude for an aircraft like the RF-104 was "high" altitude for an aircraft like the RB-50; and "high" altitude for the RF-104 was "medium" altitude for the projected reconnaissance vehicle of 1960, flying at 100,000 feet.

In these pages, for the sake of convenience, the term "high altitude" will apply to missions at 30,000 feet and above; those between 5,000 and 30,000 feet will be referred to as "medium altitude" missions, and those below 5,000 feet as "low altitude" missions. The low altitude category could be further broken down rather arbitrarily into low-low, medium-low, and high-low (treetop level, 100 to 1,000 feet, and 1,000 to 5,000 feet, respectively), although such categorizing would only detract from the clarity of the narrative.

The high altitude area search mission, as a distinct type of photographic reconnaissance, was accepted as such by the Aerial Reconnaissance Laboratory during its April 1956 conference at Monticello, Illinois.* Area reconnaissance had been carried out for many years, of course, but it had not been distinguished in any clear-cut manner from specific target reconnaissance. For example, in 1948 a reconnaissance aircraft flew a non-stop mission from Los Angeles to New York at 40,000 feet altitude making a continuous strip photograph of the ground below. The coverage was from horizon to horizon, since the aircraft employed a "tri-metrogon" camera arrangement of one vertical, one left, and one right oblique. This was area reconnaissance with a vengeance.[15]

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* See Chapter VI and VIII of this history.

In 1956, operational aircraft were equipped with several types of cameras capable of performing the area search mission at altitudes then attainable. The cameras themselves were of either 6- or 12-inch focal length, since such relatively short lens cones provided wide ground coverage from high altitude, although on a very small scale.

The 6-inch cameras used for area search included the K-17C, the K-22, the KA-2, and the T-11. The 12-inch cameras included the K-38, the KA-1, and the KA-2. Aircraft in which one or another of these cameras were installed (or scheduled for installation) were the RB-36, the RB-52, the RB-66, the RF-84F, the RF-101, the RF-104, and the RF-105. The RB-66 and the latter three fighter-type reconnaissance aircraft were not yet operational, but their complement of cameras had been at least tentatively established, and the cameras themselves were in existence.*

The K-17C camera, which in 1956 was still being used in RB-36 and RF-84F aircraft, produced nine-inch square negatives and held a magazine with 390 feet of film 9.5 inches wide. It could accommodate 6-inch (f/6.3),** 12-inch (f/5.0), and 24-inch (f/6.0) lens cones (although only the 6-inch lens was used for the area search mission). Its shutter speeds ranged from 1/50 to 1/400 of a second, and it could take pictures at a rate of one every one and one-half seconds. Its weight varied from 30 pounds with the 6-inch lens to about 53 pounds with the 24-inch lens.[16]

Installed in the RB-36 aircraft at the forward vertical camera station, a single, 6-inch focal length K-17C could handle a part of the area search mission. To obtain coverage from horizon to horizon across the line of flight, three 6-inch* K-17C's could also be mounted in a "trimetrogon" array just forward of the vertical station.[17]

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* For a detailed listing of missions, weapon systems, cameras, and focal lengths, see the charts and tables in the Supporting Documents section for this chapter. The charts and tables were compiled from sources listed in Document VII-1.

** The f-number of a lens is also called the "relative aperture" and is obtained by dividing the focal length by the diameter of the lens's "effective" aperture. It is a means of indicating the amount of light the lens transmits at various settings of the iris diaphragm.

The RF-84F aircraft utilized three 6-inch K-17C's to perform an area search mission. One camera was mounted at the vertical station and two more were mounted just behind it at right and left oblique stations. This was called a "tri-camera" array rather than a tri-metrogon since the cameras were not mounted in so precise a relation to one another as in the latter case.[18]

The K-22 was another camera used occasionally for area reconnaissance. This camera could also be found in RB-36 and RF-84F aircraft and, like the K-17C, produced nine-inch square negatives, and held 390 feet of 9.5-inch film. The K-22 could accommodate 6-, 12-, and 24-inch lens cones with the same respective f-stop numbers as the K-17C cones, and its shutter speeds ranged from 1/150 to 1/800 of a second. There were in existence 40-inch lens cones designed especially for the K-22, but none of these was installed in operational reconnaissance aircraft. The 6-inch model weighed about 25 pounds, and the weight increased to 107 pounds with the 40-inch lens. Weight increases were approximately proportional for the 12- and 24-inch models.[19]

In the RB-36, the forward vertical station was equipped to handle a K-22 camera as a substitute for the K-17C. The area search mission might thus be accomplished by using either camera equipped with a 6-inch lens cone.[20] The RF-84F camera compartment provided a forward oblique mount for the K-22; when the camera used a 6-inch cone, it could perform a kind of area reconnaissance function from this position.[21]

Another camera capable of performing the pioneer area search mission from high altitude was the KA-2. It was a much newer camera than either the K-17C or the K-22, but, although it was in production, it was intended for use in reconnaissance aircraft that were still in the development stage. The RF-101, RF-104, and RF-105 all had provisions for utilizing KA-2 cameras, and, of these aircraft, only the RF-101 was reasonably close to operational status.

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* Whenever a term like "6-inch" is applied to a camera, it refers to the focal length. Focal length, roughly defined, is the distance from the optical center of the lens to the film or focal area.

The KA-2's format size was the same as that of the K-17C and K-22 and it utilized film of the same length and width. It could accommodate 6-inch (f/6.3), 12-inch (f/4.0), and 24-inch (f/6.0) lens cones, could accomplish a cycle in 1.75 seconds, and had shutter speeds from 1/25 to 1/500 of a second. It was a considerable improvement over the other two cameras in that its operation was completely automatic, and could be installed in a torquer mount as well as in standard mounts. The weight of the 24-inch model was about 65 pounds.[22]

Although the camera itself was in production, two tasks aimed at improving its operation were still in the development stage at the end of June 1956. One was for an improved intra-lens shutter with an aperture of three and one-half inches to replace the "rapidyne" shutter in the current model. The other was for an advanced torquer mount, which was given the designation LS-6.[23]

The area search mission was tentatively allotted to 6-inch KA-2's in tri-camera array in both the RF-101 and RF-105 aircraft, and 12-inch KA-2's in the RF-104. In the RF-101, the three 6-inch KA-2's were mounted just behind the forward oblique station. The two side oblique cameras, however, faced inward instead of outward. Thus the right oblique camera took a picture of the terrain to the left of the aircraft's line of flight, and vice versa.[24]

The RF-105 called for a slightly different arrangement. The three KA-2's were mounted in the same plane across the aircraft's fuselage and were placed directly behind a single forward "rotatable" station. In this case, the two side oblique cameras faced outward as in most other tri-camera arrangements.[25]

In the RF-104, a single 12-inch KA-2 in a "rotatable" mount would perform the area reconnaissance mission from high altitude. The longer lens cone was required since "high" altitude for the RF-104 was somewhat higher than for the RF-101 or RF-105. The camera requirement for the RF-104, however, was not firm and was subject to change at any time.[26]

The T-11 camera was designed and built to extremely rigorous standards; its lens had to be especially free from distortion, since the T-11 was essentially a mapping camera. Wherever the T-11 was mounted as a single vertical camera, its mission was strictly that of mapping. However, the reconnaissance "capsule" of the RB-52 had provisions for a tri-metrogon array of T-11's which could be used for area reconnaissance as well as for charting.[27]

The camera itself used the same film and produced the same negative sizes as the KA-2 and K-17C. Its lens was a 6-inch, f/6.3 "metrogon," and it cycled once every 3 seconds. Its shutter speed range was from 1/10 to 1/500 of a second. The camera weighed about 70 pounds.[28]

Of the cameras having 12-inch lens cones, (in addition to the KA-2) the K-38 and the KA-1 were capable of accomplishing the pioneer area search mission from high altitude. The K-38 was slated for use in the RB-66, while the KA-1 was tentatively scheduled for installation in the RF-105.[29]

The K-38 had a 9-by-18-inch format and could hold 500 feet of 9.5 inch film. It could accommodate not only the 12-inch (f/6.3) cone, but 24-inch (f/6.0) and 36-inch (f/8.0) cones as well, and its shutter could be operated at speeds of from 1/50 to 1/250 of a second. The K-38 cycled once every 1.6 seconds, weighted from 37 to 62 pounds depending on the lens cone, and operated either from an intervalometer or from the universal camera control system.[30]

The 3.5-inch aperture, intra-lens shutter being developed for the KA-2 camera was being considered as an addition to the K-38. Two torquer mounts (the LS-3 and LS-4) were intended for the K-38, though they were also still in the development stage.[31]

The RB-66 was scheduled to mount a 12-inch K-38 in the vertical position just behind the tri-camera station, and provisions were already incorporated in the aircraft for installation of the camera in a stabilized or torquer mount.[32]

One other camera, the KA-1, was tentatively planned for installation in the RF-105. With a 12-inch lens cone, it could conceivably be used for area reconnaissance missions when mounted in the rear vertical position. The KA-1, like the K-38, had a 9-by-18-inch format and could handle 500 feet of 9.5-inch film. Its lens cones had focal lengths of 12 inches (f/6.3), 24 inches (f/6.0), and 36 inches (f/8.0), and its shutter operated at speeds of from 1/25 to 1/400 of a second. Its weight ranged from 55 to 78 pounds depending on focal length, and it cycled once every 1.5 seconds. Its operation was completely automatic, it was engineered to fit any standard aircraft camera mount, and plans called for incorporation of the 3.5 inch aperture intra-lens shutter in its optical system at some future date.[33]

Except for the KC-1 and the KA-3, these cameras comprised the entire stable of operational Air Force day cameras as of 30 June 1956. Used with different lens cones, they served to perform, in addition to area reconnaissance, the other daytime Air Force missions from high, medium and low altitudes.

Obviously, these cameras were already on the verge of being put out to pasture, in view of the rigorous requirements laid down in the August 1955 revision of the Technical Program Planning Document. This was not only true of the K-17C, K-22, K-38, and T-11 cameras, but also of the KA-1 and KA-2, since all of these bore a "standard" designation--and, in the Air Force, "standard" was virtually synonymous with "obsolete."[34]

Under development in 1956 were a number of cameras scheduled to replace those installed in operational aircraft. While none of them would be able to achieve completely the performance specified by the planning document, they did represent a substantial improvement over the cameras in service use. Although some might never become operational, others certainly would. At the very least, each would contribute its share to the advancement of photographic technology.

Among the cameras either in the service test or late development stage and conceivably capable of a high altitude pioneer area search missi[redacted] the E-2 panoramic camera, the KA-5 and KA-8 cameras, the LA-11 camera body, and the KA-25 camera. The latter, being developed specifically for the RB-58, was the only one of this group planned for a definite weapon system.[35]

The idea of a "panoramic" camera--one that could take horizon-to-horizon photographs without resorting to multi-camera arrangements--was not new in 1956. In March 1949, the Perkin-Elmer Corporation was developing what was then called a "transverse" panoramic camera using a rotating prism to obtain a wide "sweep" of the terrain below. The camera, designated the E-1, carried its film supply in the "roof" of the aircraft from whence it fed down through a sleeve into the format area. This arrangment allowed the use of tremendous lenths of film without the disadvantage of having to stabilize a camera weighed down with oversized magazines. The E-1 used a 48-inch lens and produced negatives 18 inches wide by several feet long.[36]

The E-1 camera served to demonstrate the feasibility of the panoramic principle. It was a very bulky machine, however, and in July 1953 the Air Force began to develop an E-2 panoramic camera that would fit in a container "similar to a wing tank." By May 1955 the contractor (Vectron, Incorporated), had fabricated an experimental model of the E-2 suitable for "nose installation in fighter type aircraft." While multi-camera arrays (such as those in the RB-36 and RB-52) were capable of obtaining about 15-lines-per-millimeter resolution, the E-2 was expected to provide something between 20 and 25 lines, since only the focal plane* and the optics of the camera needed stabilization, and since the maximum area of exposure on the film was only nine inches long and one inch wide.[37]

The experimental model of the E-2 was a "breadboard" type piece of equipment and was primarily for study purposes. It provided 150 degrees of coverage across the line of flight and incorporated a coded data recording system. It also provided "graded" image motion compensation--i.e., the compensation varied from zero at one horizon to a maximum value of 12.6 inches per second at the vertical and back to zero at the other horizon. Furthermore, exact exposure control was available for every point on the negative from horizon to horizon. This was possible because the camera utilized a focal-plane shutter which consisted of a variable-width slit sweeping across the negative plane.

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* A camera's focal plane is the area perpendicular to the lens axis, in which the image quality is best for a given focal length and lens aperture.

The E-2's weight (1,600 pounds loaded) was slightly less than that of multi-camera arrangements of the same focal length (24 inches) and its bulk was about half as great. It was more reliable, too, since its moving parts were fewer and moved at low speeds, thus cutting down the shock and vibration to which the camera was subjected. At the maximum cross section point, the E-2 was about 31 inches in diameter.

The Aerial Reconnaissance Laboratory planned to provide an E-2 camera for operational suitability testing from fiscal year 1957 funds. This model was to give a coverage of 180 degrees and to have the ability to resolve an object four feet square from 100,000 feet. At the same altitude, the camera would provide "recognition" of an object 16 feet square. The E-2 was designed to carry 5,000 feet of film which, since it moved at constant speed, was suitable for the application of rapid processing techniques.[38]

By the end of May 1956, the experimental model of the E-2 panoramic camera was nearing its "final" configuration. The principal difficulty still remaining was the need for a practical vertical gyroscope. The difficulty arose because, although there were usable instruments in existence, the better ones were assigned to projects that carried higher priorities. The contractor was thus forced to patch up gyroscopes that no one else wanted, but Vectron had not yet succeeded in putting one into operating condition.[39]

Another camera originally intended for low altitude, high speed reconnaissance, the KA-5, was in June 1956 being considered for the high altitude, area search mission. The camera produced negatives 2.25 inches square and used a magazine holding 100 feet of 70-millimeter film. Its shutter was capable of speeds between 1/25 and 1/2000 of a second, and it could cycle ten times a second. The camera weighed about 21 pounds, operated automatically, and provided "graded" image motion compensation for all mounting positions, either vertical or oblique.

The contractor for the KA-5, J. A. Maurer, had by March of 1956 delivered the first development model to the Aerial Reconnaissance Laboratory. Laboratory tests were nearing completion at the end of June.

While the low-altitude potentialities of KA-5 were not forgotten, laboratory thinking gave the camera an important part to play in high altitude reconnaissance also. In order to try the camera's abilities at high altitude, the laboratory had set up a one-time test (for some time in 1956, if possible) in which several KA-5's would be installed in an F-104 in "fan type" array. At the forward camera station, five cameras, with different focal lengths, would be arranged to give horizon to horizon coverage. The vertical KA-5 would have a 3-inch focal length; on either side of it would be an oblique with 4.5-inch focal length, each of which would be aimed to overlap the vertical's field of view; and on the outside of each of these would be another oblique of 6-inch focal length, again with overlapping fields of view. The future of the KA-5 as a high altitude camera would, in part, be conditioned by the results of this test.[40]

The Fairchild Camera and Instrument Corporation was contractor for another developmental camera with high altitude possibilities. This was the KA-8 "all-purpose" camera, which had begun development in May 1953. From the beginning, the KA-8 was planned as a high altitude camera, a low altitude camera, and a mapping camera. The laboratory received the first experimental model from the contractor in October 1954 for preliminary tests, but it was September 1955 before controls had been fabricated which would permit the camera to begin flight testing. In January 1956, several low altitude test flights were made with the KA-8, using its full image motion compensation rate of 21.6 inches per second. During the summer of 1956 comparative tests in an RB-47 were to be flown with a regular Air Force mapping camera (the T-11 or KC-1) used as a standard; after these tests had been completed, environmental testing would begin. The experimental model was equipped with a 6-inch (f/6.3) "metrogon" lens, but the service test model was to incorporate a "planigon" lens of the same focal length and speed.[41]

The KA-8 itself had a 9-by-9-inch format and used either 250 or 500 feet of 9.5-inch film. The experimental model weighed about 90 pounds without film, but the service test model would probably weigh about 60 pounds. Its shutter operated at speeds from 1/50 to 1/500 of a second, its cycle rate was six per second, it provided image motion compensation film speeds of from 0.5 inch per second to 21.6 inches per second during exposure, and it incorporated the latest improvements in automatic camera controls.[42]

The LA-11 camera body was the product of a December 1952 task intended to provide an improved camera body which could use existing K-22 lens cones. The primary goal was to develop a body that was simple, reliable, durable and easy to maintain, since the K-22 body was outstanding in none of these attributes. Using a 6-inch lens, the LA-11 would be able to fly a high altitude area search mission and produce photographs of better quality than those produced by the K-22.

By April 1956 no experimental model of the LA-11 had yet been received from the contractor, the Hycon Manufacturing

Company, the reason givenbeinginability to obtain a high enough "curtain speed" to satisfy the requirements. The laboratory hoped, however, that a model would be delivered in the "next few months."[43]

The LA-11 differed from the K-22 body in that it utilized a focal plane shutter capable of speeds between 1/100 and 1/1600 of a second. This was actually the fastest shutter speed available for any large-format, Air Force camera, either in existence or under development. The body was to incorporate automatic controls; it weighed about 30 pounds and had a cycling rate of two per second.[44]

One of the three cameras being developed especially for the RB-58 aircraft by Fairchild Camera and Instrument Corporation, was the KA-25. It was equipped with a 6-inch (f/6.3) "metrogon" lens (like the T-11 and KA-8) and could be used at high altitudes for area reconnaissance. Like the KA-8, it was also a mapping camera and a low altitude reconnaissance camera. Its format was nine inches square, and its magazine held as much as 500 feet of 9.5-inch film. Its controls were being specially designed, as was its stabilized mount, and it weighed approximately 60 pounds. It could cycle at a rate of four frames per second and provided image motion compensation at rates of between 0.16 inch and 16 inches per second. Its shutter speeds ranged between 1/50 and 1/700 of a second. Exposure was automatically controlled. The camera itself was still in the early development stage in June 1956, but the project engineer anticipated that environmental testing would begin in October.[45]

In April 1956, the laboratory began to work toward a reconnaissance camera for high altitude area search, to meet as fully as possible the requirements of the August 1955 Technical Program Planning Document. No contractor had been assigned to the development of this "sweep camera" as of 30 June 1956, but some design parameters had been tentatively established. A focal length of 100 inches was called for, the lens to be of the highest possible acuity and the camera itself to be of the smallest possible size and weight. The design was to incorporate automatic exposure controls as well as an automatic focusing device, and provisions were to be made to isolate the camera from its operational environment as completely as possible.

Graded image motion compensation was to be provided up to a rate of 3.6 inches per second, with the parameters automactically derived from the aircraft's navigation system. The sweep camera was to make use of "unitized" construction in order to give it the ability to use several different lens cones, and it was to be adaptable for use in a "rotatable" mount so that it could take advantage of a multi-window arrangement and switch quickly from left or right oblique to vertical and back again.

The task called for a focal plane shutter, on the order of that used in the E-2 camera. A rotating prism would provide the single lens with a 40-degree sweep of the terrain below. Such an angle of view would enable the sweep camera to cover the same area on the ground as four single 100-inch cameras of 9-by-18-inch format. Cycling rate was to be one per second, and each exposure would use six feet of 9.5-inch film.[46]

Daytime Target Reconnaissance from High Altitude

High altitude reconnaissance prior to World War II meant, for all practical purposes, reconnaissance at 10,000 feet. This was about as high as prewar, 12-inch focal length cameras could fly and still produce photographs that showed "pinpoint" targets in acceptable detail. A camera of 12-inch focal length yielded photographs from 10,000 feet altitude with a scale of 1:10,000, and this was the scale demanded by photo interpreters in order to evaluate targets properly. (If resolution could be raised from the usual 8 to 10 lines per millimter, then a slightly smaller scale would be allowable.) Using these pre-World-War-II parameters, useful specific target reconnaissance from 40,000 feet altitude, then, would require a camera of 48-inch focal length.

By the mid-1950's, however, the resolution of aerial cameras was consistently averaging from 12 to 18 lines per millimeter, and the cameras in operational use for the high altitude specific target reconnaissance mission had either 24-inch or 36-inch focal lengths. At 40,000 feet, these cameras yielded negatives with a scale of 1:20,000 and 1:13,333 respectively. While photographs at such scales were "marginal" from the photo interpreter's standpoint, it was usually possible to extract from them the minimum information necessary for target evaluation.

> The cameras in production as of 30 June 1956 for use in the high altitude specific target mission were the K-22, the K-38, the KA-1, and the KA-2. They used either 24-inch or 36-inch lens cones (sometimes both), and they were either installed or planned for installation in the RB-36, RB-47, RB-52, RB-57, RF-84F, RF-101, RF-104, and RF-105.[47]
>
> Each of these cameras with a shorter lens cone, was used in the area search mission. The RB-36 carried a pair of 24-inch K-22's, one at the left and one at the right oblique station, and they were used to obtain high altitude photographs of specific targets from relatively long slant ranges. The RB-36 might also mount a 24-inch K-22 at the vertical station (in place of the 6-inch K-17C or K-22 for area reconnaissance) to obtain target evaluation photographs.[48]
>
> The RF-84F provided two positions in which the 24-inch K-22 might be located for flying specific target missions. One was the forward oblique station, and the other was the left oblique position, just behind the tri-camera array. The forward oblique K-22 doubled as a low altitude camera, but, as might be expected, low altitude photographs with a 24-inch camera exhibited extreme foreshortening effects.[49]

In 1956, the K-38 camera was being used for the high altitude specific target mission in more aircraft, in more configurations, and in more mounting positions than any other. In the RB-36, a pair of 24-inch K-38's were mounted at the "split vertical" station for target evaluation shots; just behind them, five 36-inch K-38's were set up in a "multiple" array for the same purpose. The split verticals performed a second function whenever the RB-36 was on a mapping mission. While the mapping camera (which had a 9-by-9-inch format and a 6-inch lens) made one exposure, the split verticals (each of which had a 9-by-18-inch format and a 24-inch lens) would have made four. Thus the split verticals produced 36-inch-square negatives of the same field of view covered by the mapping camera. The quadrupled scale of the K-38 photographs assisted in positive identification of details on the mapping prints.

The multiple array of 36-inch K-38's was also capable of performing a mission secondary to that of specific target reconnaissance. These cameras could be used, over limited ground distances, for area search missions. They provided lateral coverage of about 108 degrees, and, whenever the aircraft's viewfinder indicated an especially interesting area below, they could be operated to obtain overlapping photographs of the terrain at a relatively large scale. Here again, the K-38 shots would aid considerably in identifying detail on the small-scale photographs taken by the 6-inch focal length "area search" camera.[50]

Single vertical K-38 cameras of either 24-inch or 36-inch focal length were mounted in both the RB-47 and RF-84F. The RB-47 also carried a 24-inch forward oblique and a pair of 24-inch or 36-inch split vertical K-38's while the RF-84F was capable of mounting a 36-inch K-38 obliquely in its nose compartment. All of these were used primarily for specific target reconnaissance from high altitude, with the split verticals in the RB-47 supplementing the mapping camera in the same manner as those in the RB-36.[51]

The RB-52 and RB-57 also had mounting provisions for K-38 cameras. The RB-52 reconnaissance "capsule" was designed to carry a multiple array of four 36-inch K-38's for specific target high altitude missions. The RB-57 could utilize a pair of 24-inch split vertical K-38's for either high or medium altitude target evaluation work. As in the case of the split verticals in the RB-36 and RB-47, those in the RB-57 supplemented the work of the 6-inch mapping camera.[52]

The newer KA-1 and KA-2 cameras were all planned for installation in fighter type reconnaissance aircraft, none of which were yet operational. The RF-101 was to carry a pair of split vertical 36-inch KA-1's for specific target reconnaissance from high altitude, and the RF-104 a single vertical of the same focal length. The RF-105 had provisions for KA-1's in three different mounting positions. At the split vertical station, the aircraft could carry a pair of 36-inch focal length cameras. In the vertical spot could be placed either a 24-inch or 36-inch KA-1, and the same choice of cameras was available at the forward oblique position.[53]

There was a possibility that the KA-2 camera might also be used for specific target missions from high altitude. The RF-105 was to have the ability to carry a single 24-inch KA-2 in the forward oblique compartment in place of the KA-1.[54]

In the "service test" category as of 30 June were four new cameras or bodies which, presumably, would be able to perform a high altitude specific target mission under operational conditions. These four were the LA-11 body, KA-5 camera, plus the KA-13, and the KA-27 (which, like the KA-25, was being developed for used in the RB-58 only). The LA-11 body, using a 24-inch cone, was expected to improve markedly on the performance of the K-22 camera.[55]

While the KA-5 camera was being developed almost exclusively as a low altitude reconnaissance camera, with a secondary possibility of flying a high altitude area search mission, the Aerial Reconnaissance Laboratory intended to try it out on the high altitude specific target mission as well. During the same F-104 test flight on which the five short focal length

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KA-5's were to be tested as area search cameras,* the laboratory intended to test a tri-camera grouping of 12-inch focal length KA-5's.[56]

Under development for operational use in the immediate future as a high altitude camera for specific target reconnaissance was the KA-13, a camera with a 9-by-18-inch format using up to 1,000 feet of 9.5-inch film. The Hycon Manufacturing Company reported in June 1956 that an experimental model would be delivered to Wright Field "shortly."

The KA-13 was not a radically new or different design, but merely incorporated a number of state-of-the-photographic-art advances in a relatively conventional camera body. It was to have image motion compensation, which existing 9-by-18-inch format cameras did not have. It was to be equipped with automatic exposure controls and with a coded data recording device. It was also to have a fast focal plane shutter (with speeds up to 1/800 of a second) and a cycling rate of two frames per second.

The camera would utilize four different lens cones for photographic missions at various altitudes. In addition to accepting the 12-inch (f/6.3), 24-inch (f/6.0), and 36-inch

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* See page 32.

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(f/8.0) lenses originally planned, the KA-13 was also to take cones containing 48-inch (f/6.3) lenses of which 300 were already in Air Force stock. These cones were unusable in any other Air Force camera, since they were designed to be used with a focal plane shutter. There was hope that, with improvements, the 48-inch cone would extend photographic altitudes at a sufficiently early date far enough above 60,000 feet to satisfy the "100,000 feet by 1960" requirement in the Technical Program Planning Document.[57]

The KA-13 would weigh about 330 pounds with its 48-inch lens cone and 1,000 feet of film. Its image motion compensation rates varied between 0.1 inch per second and 3.6 inches per second, and it was to be compatible with most standard aerial camera mounts.[58]

The KA-27 was a 36-inch focal length camera being developed for use in the RB-58, strictly for the high altitude specific target reconnaissance mission. Like the KA-25 and KA-26, it was being built by the Fairchild Camera and Instrument Corporation, and, as of June 1956, was still in the early development stage.

It was to have a 9-by-18-inch format, could use up to 500 feet of 9.5-inch film and was to be compatible with lens cones longer than the 36-inch (f/8.0) cone currently planned for it. Its shutter was to be of the intra-lens "rapidyne" type with speeds of between 1/100 and 1/300 of a second. The KA-27 was not a fast cycling camera; its fastest rate was one frame every 1.25 seconds. Its rate of image motion compensation built up to a maximum of 3.2 inches per second. Camera weight was about 100 pounds. Controls were of special design, and its mount was to be gyro-stabilized.[59]

More advanced than the requirements for any of the above four cameras were those laid down in January 1956 for a "very high altitude duplex" camera. No contractor had been assigned to the development by June 1956, but the performance parameters were designed to meet as fully as possible the requirements of the August 1955 planning document.

The purpose of the task was "to provide high resolution, moderate scale aerial photography from future operational altitudes by camera systems mounted in supersonic aircraft compartments that are neither pressurized or [sic] thermally controlled. . . ." The camera itself was to have a 9-by-18-inch format, actually two formats, since it was a duplex with two optical systems in one body, and focal lengths of 36 (f/8.0) or 48 (f/11.0) inches. The task called for elimination of all mechanical tolerances between the lens mount and the focal plane, high quality production lenses, complete elimination of internal and external vibration of the camera system, and improved film.

Perhaps the most remarkable development goal was a resolution of 100 lines per millimeter ("on the bench"). An intra-lens shutter with an aperture of three and one-half inches was to be designed for use in the 36-inch or 48-inch cone. Shutter speeds would range from 1/50 to 1/2000 of a second. It was contemplated that a single photoelectric cell would control both shutters.

There was to be no image motion compensation in the ordinary sense, but movement of the image was to be offset by using a swinging torquer mount. Total weight of the loaded camera was to be about 190 pounds. The camera was to carry up to 500 feet of aerial photographic film; or more if thin-base film could be successfully developed. Using 500 feet of film, the camera could cover a strip 35 miles wide and 580 miles long (using the 36-inch cone) at 60 percent overlap from 100,000 feet altitude. On a normal development basis, an experimental model of the camera could be expected within two years after signing of a contract.[60]

Development of high resolution lenses held an important niche in the high altitude camera research structure. Of the score or more lens developments underway in the Aerial Reconnaissance Laboratory, three were of special importance for high altitude reconnaissance, one for the area search mission, and two for the specific target mission.

For possible future use in area search reconnaissance, the laboratory early in 1956 established a task calling for a 12-inch focal length lens for a 4.5-inch square format. No contractor had been selected by the end of June, but the lens characteristics required that it resolve 60 lines per millimeter, that it have reasonably high speed, and that it be capable of obtaining extremely high quality photographs from very high altitude. Aspheric-surface lens elements or even a curved image plane would be permitted in the design of the lens.*[61]

Two other high altitude lenses, one of 36-inch focal length and the other of 48-inch focal length, still lacked a contractor by the end of June 1956. The 36-inch lens was to have 60-lines-per-millimeter resolution (more, if possible), and it was to be designed especially for use in the very high altitude duplex camera. The laboratory planned to procure two competitive prototype models of the lens.[62]

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* Portions of a lens surface that are non-spherical are called "aspheric." A curved image plane is incorporated in certain experimental cameras to bring every part of a photographic image into sharp focus. A flat image plane causes areas away from the center of an image to be less sharply defined than those nearer the center.

The 48-inch lens was to have at least twice the resolution of any comparable lens (this meant between 30 and 40 lines per millimeter). Project engineers planned to investigate a "folded" lens system which would permit the length of the camera to be along the longitudinal axis of the aircraft.[63]

Daytime Target Reconnaissance from Medium Altitude

Medium altitude reconnaissance was on the way out by 1956, although great numbers of operational aircraft still were equipped with cameras suitable for the medium altitude mission, and several cameras in development were aimed at the same mission area.

"Medium" meant, generally speaking, between 5,000 and 30,000 feet, and generally required a focal length of 12 inches to obtain the necessary detail. Thus, the 12-inch cone was characteristically mated with one of the operational high altitude cameras whenever medium altitude reconnaissance was required.

> The RB-36 and RF-84F both had provisions for mounting a 12-inch K-17C or K-22 at vertical stations. In addition, the RB-36 could utilize one forward oblique and two side oblique (left and right) K-22's of 12-inch focal length for medium altitude specific target photographs. The RF-84F could carry the same cameras at both forward oblique and left oblique stations.[64]
>
> Vertical 12-inch K-38's were to be mounted, on occasion, in the RB-66 and in the reconnaissance capsule of the RB-52; there was also a provision for the RF-105 to carry

a single vertical 12-inch KA-1. The other existing camera planned for medium altitude work was the KA-2. "Rotatable" 12-inch KA-2's were scheduled for installation in both the RF-104 and RF-105, while forward oblique KA-2's of the same focal length were to be mounted in RF-105 and RF-101 aircraft.65

Medium altitude cameras still in development included the KA-13 and LA-11. Both 24-inch and 12-inch cones were planned for the KA-13, and this made the camera suitable for medium altitude work. The LA-11 body would operate at medium altitude with a 12-inch cone just as the K-22 did.66

The Hycon Manufacturing Company was developing a camera, the KA-4, which represented a considerable step forward on the road to obtaining a truly up-to-date, high-acuity medium altitude reconnaissance camera. Designed primarily for high speed, low altitude photography, the KA-4 nevertheless was to be usable with a 12-inch cone for medium altitude shots. Its format was four and one-half inches square and it carried up to 500 feet of five-inch film in its magazine.

It was a fast-acting camera. Its focal plane shutter could operate at speeds up to 1/1000 of a second, it could cycle six times per second, and its film could be moved during exposure at a rate of 10.8 inches per second for image motion compensation. Its lens was fast, too (f/4.0 for the 12-inch cone), and the camera's weight was about 45 pounds. The camera design allowed installation in any standard Air Force mount, and such features as automatic exposure control and coded data recording were incorporated in the camera body.[67]

The contractor delivered the first experimental model of the KA-4 to the Aerial Reconnaissance Laboratory at Wright Field early in 1955; flight testing in an RF-84F had begun by the end of the year. These tests were considered successful and, by March 1956, plans were being made for procurement of a service test quantity of 21 cameras by late 1958.[68]

Daytime Target Reconnaissance from Low Altitude

The region below 5,000 feet altitude, like that above 30,000, was becoming increasingly important to aerial reconnaissance camera designers by 1956. In low-altitude operations, problems of navigation and precise location of targets were intensified, but low-flying reconnaissance aircraft had the compensating ability to get in and out of target areas without overmuch exposure to defensive fire. The chance of interception by enemy radar, missiles or antiaircraft fire was greatly lessened.

The value of low altitude reconnaissance was brilliantly illustrated in September 1950, during the Korean fighting, by three RF-80 pilots from the Fifth Air Force. They made four very-low-altitude flights over the invasion beach at Inch'on, trying to get pictures which would show the height of the seawalls and to locate defensive armament, sandbars and shoals which might snag landing attempts. The RF-80's, using K-22 cameras, made both vertical and oblique shots, some in heavy overcast and drizzling rain. The verticals were taken from about 3,000 feet altitude, while the obliques were shot as the aircraft streaked toward the beach at altitudes between 100 and 300 feet.

Results were excellent. Invasion forces based their plans for an assault on the seawall height data derived from the photographs. Amphibious troops stormed ashore equipped with the necessary ladders, and went over the seawalls easily. The walls proved to be almost exactly the height calculated from photographs. Oblique views of the beaches from various distances off shore also proved invaluable to the crews operating landing craft.[69]

In general, low altitude, high speed reconnaissance photography required short focal length lenses, high shutter speeds, and high image motion compensation rates. Most of the low altitude cameras operational in June 1956 used 6-inch lens cones almost exclusively, but some cameras under development were to have lenses of 3-inch--and even 1.5-inch--focal length.

> The venerable K-17C and K-22 cameras still served on low altitude reconnaissance missions in the RF-84F. The tri-camera array of 6-inch K-17C's used for area reconnaissance missions did double duty and performed

low altitude missions as well; the same held for the forward oblique 6-inch K-22, but, on occasion (as in the case of the RF-80-s in Korea), a 24 inch K-22 was mounted at the forward oblique station for low altitude reconnaissance.[70]

Other existing cameras planned for operational use in reconnaissance aircraft still in the development stage were the KA-1 and KA-2. Tentatively, a 12-inch KA-1 camera, mounted at the vertical station of the RF-105, was to serve in a low altitude capacity in addition to performing area search and medium altitude reconnaissance functions. KA-2 cameras with 6-inch lenses were slated for installation in both RF-104 and RF-105 aircraft; in the RF-104, the KA-2 to be installed in a rotatable mount and used strictly for low altitude work. In the RF-105, however, a tri-camera arrangement of 6-inch KA-2's doubled as high altitude area search cameras. The RF-105 was being engineered to use both 12-inch and 24-inch KA-2's for low altitude missions as well as the primary missions for which the cameras were designed. While the 12-inch KA-2 was first of all a medium altitude camera for either rotatable or the forward oblique mounting, using it for low altitude missions was certainly possible and such a contingency was provided for. Similarly, the 24-inch model was intended largely for high altitude target reconnaissance, but (again as in the case of the 24-inch K-22 in Korea) when mounted as a forward oblique in the RF-105, it could be valuable for low altitude missions.[71]

The only production camera specifically designed for low altitude missions was the KA-3. Equipped with 6-inch lenses, these cameras were installed in the tri-metrogon mounts of RB-47's for exclusive use in low altitude reconnaissance.[72]

The KA-3 camera had a 9-inch square format and used up to 390 feet of 9.5-inch film. As of June 1956, it could use only one focal length lens (6 inches) and it was installed in only one type of aircraft, the RB-47. The camera weighed about 30 pounds and was capable of cycling twice every second. Its fastest shutter speed was 1/400 of a second--rather slow for low altitude work--but it provided image motion compensation rates as high as seven inches per second. The KA-3 had been engineered for installation in a torquer mount, but in operational use it appeared only as a tri-metrogon.[73]

The Air Force's stable of developmental low altitude cameras had an Augean look at first glance, simply because the quantity of hardware was so large. Appearances were deceiving, however, and cleaning out the less important items required something less than herculean efforts. Five of the cameras planned for the low altitude mission were also intended for high and medium altitude reconnaissance, and only two were exclusively low altitude cameras.

The KA-4 camera was being developed for low as well as medium altitude work. In the latter application this camera utilized a 12-inch lens cone. The low altitude model of the KA-4 would accommodate either a 3- or a 6-inch lens, however.[74]

The KA-5, ostensibly a high altitude area search camera, was also a good bet to perform the low altitude mission. Like the KA-4, the KA-5 would utilize both 3- and 6-inch lens cones, but, in addition, a 1.5-inch cone was to be developed especially for it. There was some thought among Aerial Reconnaissance

Laboratory personnel that a 9-inch cone might also be designed for the KA-5, but the requirement for such a cone was not yet firm.[75]

It was possible that the KA-13 camera, using a 12-inch lens cone, would also serve for low altitude missions, although plans for the KA-13 concentrated primarily on higher altitudes. The KA-25 and the LA-11 were both definite contenders in the low altitude race. The KA-25, a 6-inch focal length camera destined for installation in the RB-58, was a high altitude area search camera like the KA-5 and KA-8 but it could perform adequately in a low altitude mission, and plans for its development foresaw just such a function. The LA-11 body, using either a 6-inch or 24-inch cone, would almost certainly see future duty as a low altitude reconnaissance camera, particularly in view of its fast shutter speed (1/1600 of a second).[76]

Except for the KA-5 and KA-4, these cameras had one serious drawback in operating at low altitudes. They had large formats (either 9 inches square or 9 by 18 inches), and this meant mechanical difficulties aplenty when high image motion compensation rates were attempted. It also meant that for focal lengths shorter than 6 inches, unusually wide-angle lenses would be essential. In view of these circumstances, the trend in low altitude cameras was toward the use of 70-millimeter film. The KA-4's 4.5-inch square format was still somewhat large for truly high speed operation, but the KA-5 used 70-millimeter film, as did two other low altitude cameras, the KA-26 and KA-16.

The KA-26 was one of the three cameras being especially designed for use in the RB-58; it was to be exclusively a low altitude mechanism. It produced a 2.25-inch square exposure on 70-millimeter film carried in a 250-foot capacity magazine, and it relied on a 3-inch, f/1.5 lens. Its shutter was to be capable of operating at speeds up to 1/4000 of a second, eliminating any need for image motion compensation and special mounts. The camera could be rigidly mounted to the airframe since the fast shutter speed would nullify vibration and motion effects. The KA-26 would cycle about 7 times per second and would weigh between 14 and 18 pounds. Like the KA-25 and KA-27, the KA-26 was still in the bench testing stage at the end of June 1956.[77]

Very similar to the KA-26, although not being designed for a specific weapon system, the KA-16 camera also used 70-millimeter film and had a 2.25-inch square format. The contractor for the KA-16, the Bulova Watch Company had by June 1956, delivered three experimental models of the camera to Wright Field. The KA-16, like the KA-26, depended on high shutter speed (up to 1/4000 of a second) to reduce image blur and had no provision for synchronizing movement of the film during

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exposure with movement of the image across the focal plane. Comparative tests of two different lenses, one f/1.5, the other f/2.0, both of 3-inch focal length, were to show which was most appropriate for the KA-16's low altitude mission. The camera would, of course, incorporate automatic exposure control and coded data recording, and it would cycle 6 times per second.[78]

Aerial Mapping

The requirements for an aerial mapping camera were extremely rigorous, not only from the optical standpoint of high resolution, excellent definition, and lack of distortion, but also from the standpoint of mounting provisions. Such a camera had to compensate for or overcome speed and vibration effects, had to be mounted so that it was vertical, and the resultant aerial photograph had to be compatible with accurate maps of the area covered.

General operational requirements of 1955 called for aerial mapping from altitudes so high and with accuracies so great as to be completely beyond the scope of current equipment or current knowledge. The Air Research and Development Command Technical Program Planning Document on photography deliberately

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understated the problem in cautioning, "considerable development work will be required to provide this capability."[79]

Command headquarters, in a technical requirement that followed in the wake of the planning document, called for the establishment of a "sound research and development program" that would result in a "time-phased increase in the amount of detail that can be recorded on film and thus provide an effective substitute for increased focal length, bulk and weight of aerial equipment, and the present production of fantastic quantities of negatives and prints." Headquarters expressed the hope that ultimately, "a single small photograph taken from very high altitude will yield, when examined by a microscope, the same amount of information that now is extracted from thousands of aerial photographs."

The official requirement for aerial mapping cameras specified an exacting development schedule. By 1960, navigational maps prepared by reference to aerial photographs were to show details which could be pinpointed to within 1,500 feet of their true position and within 100 feet of their true elevation above sea level. Larger scale "target " maps were to enable the pinpointing of details to within 500 feet of their location and 50 feet of their elevation.

By 1965, all maps based on aerial photography were to meet the requirements of the 1960 "target" maps, and the photographic mapping system itself was to be of "very high acuity" and of "half the format size and focal length of present mapping photography." After 1965, accurate mapping photography from earth satellites was to be the objective.[80]

In 1956, the altitude limits and accuracy of aerial mapping cameras were far removed from the optimistic requirements of the technical program. Mapping cameras could operate to about 25,000 feet altitude, considerably below the 60,000 feet desired by 1960 or the 300 miles desired soon after 1965. Points on the ground could be located on 1956 aerial photographs to within 2,000 feet of their true geographic position, but this was only possible at relatively modest altitudes.[81]

The cameras in operational use throughout the Air Force for aerial mapping were the hoary K-17C, the T-11, and the relatively new KC-1. The K-17C was not ordinarily considered a mapping camera, but it served on occasion in that capacity in the RB-36. The mapping camera called for in most operational aircraft was the T-11. Single vertical T-11's could be mounted in the RB-36, the RB-47, the RB-57, the RB-66, and the RF-84F, while three T-11's in a tri-metrogon array could be mounted in the capsule of the RB-52. Naturally, only the vertical camera of a tri-metrogon group was the actual mapper. The two side obliques aided in determining the flight attitude of the aircraft by showing the position of the horizon on the left and right.[82]

In June 1956, a replacement mapping camera was in production. This was the KC-1, manufactured by the same company (Fairchild Camera and Instrument Corporation) that made the T-11. It was interchangeable with the T-11 in all standard Air Force mapping mounts. The KC-1 differed very little from the older camera, having the same format, film width, lens, shutter speed, and mount. It was, however, about 20 pounds heavier, and it cycled somewhat faster (once every two instead of every three seconds). The KC-1 was also built with an integral magazine.[83]

All of these cameras had one thing in common--they were used for mapping as single verticals only. This was a definite disadvantage, because as photographic altitudes increased, the determination of the heights of ground objects became almost impossible from single prints. Accurate contouring of maps thus developed into a major problem area. By early 1955, the trend was toward twin camera installations and development of the "duplex" camera--one that embodied two convergent optical systems in a single body. Convergent photography was also strongly advocated by the Corps of Engineers, since it permitted more accurate determination of ground contours and object heights from high altitude and aided the photo interpreter in other ways. The engineers indicated they would need a convergent mapping system by 1960, and urged Air Force establishment of a development program to this end.[84]

In January 1956, the Aerial Reconnaissance Laboratory began work on "convergent mapping cameras" capable of self-sustained operation at extremely high altitudes and under extremely low pressures. This high priority task required a 6-inch, f/6.3, focal length, distortion-free, wide-angle lens, a 9-inch square format, and very high acuity. The convergent system was to be capable of resolving a 20-foot object and of identifying an 80-foot object at a scale of 1:50,000; it was to be light and compact, and it was to fit in a precisely engineered torquer mount.[85]

On 18 July 1956, the laboratory's Reconnaissance Camera Section recommended converting the KC-1 into a duplex mapping camera. The schedule laid down in the task plan called for delivery of the first experimental model within 18 months of the signing of the contract.[86]

Night Target Reconnaissance from High Altitude

Night photographic reconnaissance by mid-1956 was concentrated in either the high or the low altitude region. Medium altitude night cameras, which included the K-36 and the newer K-37 and K-47 cameras, would continue to serve until operational altitudes finally outran their capabilities.

The high altitude requirement for night cameras called for reconnaissance photography by 1960 at altitudes of 70,000 feet with the ability to recognize objects five feet square on the ground. Since night photographs in 1956 were scarcely able to provide recognition of objects 20 feet square from 30,000 feet, intensive development both of cameras and illuminants was essential.[87]

Night photography involved several serious problems from which day photography was insulated. Perhaps most important was the need for artificial illuminants which packed tremendous candlepower potentialities into relatively small containers. Even with this aid, night photographs required long exposure times and this, in turn, required extremely accurate image motion compensation. Night cameras also needed more control equipment than their daytime couterparts--for example, a timing mechanism for synchronizing the shutter with the explosion of the photoflash bomb or cartridge was mandatory. Moreover, due to their greater complexity, night photographic systems were more expensive, as well as less reliable, than daytime systems.[88]

Night cameras being used operationally in 1956 for high altitude specific target reconnaissance included the K-36 and K-37. While the K-47 (a replacement for the K-37) was in production, it had not yet been installed in operational aircraft, although its use in the RB-66 had been scheduled.[89]

As of June 1956, the somewhat antiquated K-36 still was scheduled for installation in the rear vertical mount of the RB-52 reconnaissance capsule for high altitude night photography. The camera would be equipped with a 24-inch lens cone, and the aircraft would carry 24 large flashbombs (M-120A1) for illumination.[90]

The K-36 itself had a format 9 by 18 inches and had the disadvantage of requiring 18.5-inch film, of which its magazine carried up to 100 feet. It was engineered to accept either a 24-inch or 36-inch cone, although in 1956 no operational aircraft could use the latter without special installation. The 24-inch model had an intra-lens shutter and cycled at the respectable rate of once every second. Its maximum image motion compensation rate was five inches per second, and the camera was designed for installation in a torquer mount. With the cone attached, the K-36 weighed about 260 pounds.[91]

Most high altitude night missions were assigned to the 12-inch focal length K-37 camera. Provisions for mounting this camera as a single vertical were made in the RB-36, the RB-47, the RB-52's capsule, the RB-57, the RB-66 and the RF-84F. In addition, pairs of K-37's were mounted in both the RB-47 and RB-57 at split vertical stations, although they were used primarily for low altitude photography in the latter aircraft.[92]

The K-37, which was about to be phased out of operational use, was a 9-by-9-inch format camera using up to 390 feet of 9.5-inch film. It had only one focal length (12-inch, f/2.5) and operated at a top shutter speed of 1/100 of a second. It cycled once every 2.5 seconds and weighed in the neighborhood of 57 pounds. A torquer mount (LS-6) being developed for use with it would probably not be operational before the K-37 went out of service use.[93]

The K-47, which went into production in May 1955, had the same film capacity and format as the K-37 it was slated to replace; it could use either 12-inch, f/2.5, or 24-inch, f/4.0, lens cones. Maximum shutter speed was 1/200 of a second, twice as fast as the K-37 shutter, and the camera was capable of cycling twice every second when used with a magazine with provisions for image motion compensation or once every two and one-half seconds otherwise. It was manufactured by Fairchild, and was designed to fit the same torquer mount (LS-6) being developed for the K-37.[34]

Under development to meet the rigorous requirements of the 1960 to 1965 period was a camera that would, if perfected, represent a real "breakthrough" in high altitude night—and even daytime—photography. This was the "curved field" night camera, for which the University of Rochester had developed an experimental lens as early as 1954. The Aerial Reconnaissance Laboratory felt that if sufficient funds were provided, this type of camera could be developed quickly enough to make the difficult transition from 30,000 to 70,000 feet in the short space of five years and at the same time meet the high resolution requirements.

The f/1.0 lens had been delivered to the laboratory in mid-1954, and by the end of the year flight tests of a "bread-board" model camera were under way. During these tests, usable night photographs were obtained from 11,000 feet using a one-pound photoflash cartridge. This was double the altitude at which night photographs had hitherto been taken with the same cartridge and the best 6-inch lens in the Air Force inventory. The tests indicated considerable promise for development of a night photographic system which would be relatively small in size and weight and would require a minimum of artificial illumination from high altitude.[95]

With the feasibility of the curved field camera proved, the laboratory in March 1955 began to develop a 24-inch f/2.0 lens and curved-field night camera for high altitude reconnaissance. Test results had shown that such a camera could realize 70 percent higher acuity than flat field cameras in current use, and that it required only about one-fourth the artificial illumination currently deemed necessary. Plans envisaged three of these cameras swinging in a single torquer mount and photographing through a single window. One camera would be a vertical and would aim directly ahead of the flash bomb burst; the other two were left and right obliques.[96]

By early 1956, requirements for the advanced camera were available in a little more detail. The camera was to have double the acuity of current cameras, was to utilize illuminants and was to weigh only one-third as much as cameras currently in use. It was to be capable of self-sustained operation at high altitudes, low temperatures, and near-vacuum conditions. Designers hoped it would resolve a seven-foot object or identify a 28-foot object on the ground at a scale of 1:50,000. Coded data recording was mandatory. Since all film handling would be rapid and automatic, the Air Force planned to study higher speed film for possible application in this camera, and even airborne rapid processing would be considered. The Aerial Reconnaissance Laboratory anticipated that contemporary night high altitude photographic system weight could be reduced from over 14,000 pounds to about 4,000 pounds, and that an experimental model of the camera and lens would be delivered within 18 months of the signing of a contract and the receipt of funds.[97]

Night Target Reconnaissance from Low Altitude

The Air Force's low altitude equipment for night photography was, in 1956, grossly inadequate to meet requirements. While it was true that when the Korean fighting began the Photographic Laboratory at Wright Field had a low altitude night reconnaissance system ready for use, that system was extremely crude and unreliable, and whatever useful information it provided was more the product of skilled operators and interpreters rather than the excellence of the equipment.

> Because of various adverse factors, not the least of which were the dearth of funds and the relative lack of emphasis by higher headquarters on low altitude night photography, by mid-1956 the backbone of the low altitude night reconnaissance mission was still the marginally

adequate 12-inch focal length K-37. A newer night camera with a smaller format (4.5 inches square) and shorter focal length (7 inches) was the K-46, but it was scheduled for installation in the RB-66 and RF-101, neither of which was yet operational.[98]

Low altitude night photographic missions could be flown by the RB-47 and RB-57, each aircraft utilizing a pair of split vertical K-37 cameras. The RB-47 carried 200 flash cartridges (M-112) for illumination, while the RB-57 could carry 208 of these, or 80 of larger size (M-123). The RF-84F could use its single vertical K-37 for low as well as high altitude night missions; for illumination, the aircraft carried 208 small (M-112) or 160 large (M-123) photoflash cartridges.[99]

The K-46 camera was slated for mounting in RB-57, RB-66 and RF-101 aircraft. In the RB-57, three K-46's could be installed to make up a tri-camera array, two being placed in the forward split vertical stations, and one at the rear vertical station. As of 30 June 1956, however, this installation had not been made in operational RB-57's. The RB-66 and RF-101 were also engineered to accept tri-camera K-46 groups. In the RB-66, the K-46's were to be mounted at the forward stations, where the centerpoints of all three lay in the same plane cutting across the aircraft's fuselage. It was planned that the RB-66 would carry 104 small or 40 large flash cartridges.

The tri-camera mounting for low altitude night reconnaissance in the RF-101 incorporated a single vertical camera just ahead of a pair of split verticals. For illumination, the RF-101, like the RB-66, would carry either 40 large photoflash cartridges or 104 small ones. An alternate arrangement permitted a combination of 20 large and 52 small cartridges.[100]

The K-46 night camera, made by Hycon, used up to 250 feet of 5-inch film per load and had a format 4.5 inches square. The only production lens cone it could use contained a 7-inch f/2.5 lens, although development of a 6-inch lens cone was in progress. The 35-pound K-46 could cycle twice per second and it had image motion compensation rates as high as 15 inches per second. A torquer mount (LS-6) was in development for use with the K-46, as well as several other aerial cameras, and the K-46 was also compatible with the Air Force universal camera control system.[101]

Early in 1956, the laboratory started work on a night camera that could meet low-altitude requirements for the 1960-1965 period. The task called for a duplex camera capable of operating under adverse light conditions and compatible with flash bombs, flash cartridges, mercury arc lamps, and possibly even infrared or atomic radiation. Project engineers anticipated that the new camera with two sets of optics in one body would give the same coverage provided by a tri-camera array of K-46's, and that great reductions in camera weight and window sizes could be realized. The camera was to have a very fast shutter, an image motion compensation rate as great as nine inches per second, and was to be capable of cycling five times per second. Ultimately it would be mated to a 4.5-inch focal length lens cone of very high acuity, but for the immediate future a 6-inch lens cone would be adequate. Negative format would be 4.5 inches square, in a camera body requiring a built-in flash detector of extremely high sensitivity.[102]

Illuminants and Light Detectors

By 1956, night photo-illuminants were producing about five times as much light as their World War II forebears, but they were also at least twice as heavy. One of the immediate tasks facing Air Force and Ordnance pyrotechnic engineers was thus the reduction of bomb and cartridge weights for use in high speed, fighter type reconnaissance aircraft, and at the same time to increase light output even further.

The 165-pound M-120A1 photoflash bomb of 1956, with a light output of something over 2,000,000 candlepower and capable of producing usable photographs from 40,000 feet with an f/4 lens, was a far cry from the World War II M-46, which was barely adequate for night photography at 9,000 feet. Nevertheless, no fighter type aircraft could carry many 165-pound bombs and still have room for cameras. Luckily, tests during 1955 had pointed the way to a substantial reduction in photo-illuminant weight.

Photoflash cartridges (M-112) weighing just about one pound were used in a series of night photographic experiments in conjunction with a 24-inch, f/4.0, K-47 camera. Photographs at altitudes from 6,000 to 10,000 feet in 1,000-foot increments, prompted the conclusion that a 40-pound flash bomb could be built which would make 40,000-foot night photography feasible! The efficiency of the flash powder being used in newer Air Force cartridges was phenomenally higher than even a year before, and this increase was due almost entirely to manufacturing techniques rather than to new ingredients.

There was still plenty of opportunity for the prime pyrotechnic development agency, Picatinny Arsenal, to create new compounds of vastly higher efficiency, and thus pave the way for the Air Force to design aerodynamic bomb shapes suitable for supersonic, high altitude release.[103]

Early in 1956 the laboratory began to coordinate and unify the development of flash compounds, fuzing systems, and bomb shapes so that night photography at altitudes mentioned in the technical requirements could become possible. By making advances in each of these areas, and by trying such new techniques as detonating strings of flash bombs simultaneously, the Air Force believed that the altitude requirement could be met with a bomb package smaller than the M-120A1.[104]

Low altitude night photography was not overlooked in the search for better illuminants. In development was a "mini-flash" system for the altitude region between 500 and 1,500 feet, a system designed to apply miniaturization techniques to the low altitude photoflash equipment already in operational use.[105]

The Aerial Reconnaissance Laboratory was monitoring development of other illuminants in addition to those utilizing flash powder. Not the least important of these was the continuous-source airborne floodlight. Xenon-filled flash lamps of high intensity and short duration had been used during World War II with indifferent success, but developments and tests since that time had wrought vast improvements in the electrically-operated light source field.

One undertaking that held great promise for the low altitude range from 500 to 8,000 feet involved a mercury arc illumination system to be carried in the wingtip pods of fighter type reconnaissance aircraft. Flight tests in 1955, performed in a C-47 equipped with 3 mercury arc lamps, proved the feasibility of such a system at speeds below 180 miles per hour and altitudes below 2,500 feet. Upon completion of these tests, two contractors (AiResearch Manufacturing Company and Marquardt Aircraft Company) began to develop 12-lamp mercury arc illumination systems. Both systems were to be powered by ram-air turbine-driven generators installed in wingtip tanks and tested in an RF-84F at Wright Field.[106]

By March 1956, the Aerial Reconnaissance Laboratory had received from each contractor a 12-lamp system capable of providing about eight times the illumination previously obtained from the C-47 installation. The laboratory analyzed the units structurally and by 15 May had installed them in an RF-84F for flight testing. The airborne test was well under way on 30 June, and plans were being laid for fabrication of an experimental 21-lamp mercury arc system by 1957.[107]

In the case of a continuous light source carried in the aircraft, synchronization of the camera shutter with a flash of light was not a problem. When bombs or cartridges were used, however, the synchronization problem was considerable. The bomb or cartridge had to be released so as to explode after falling about two-thirds the distance from the aircraft to the ground, and the trajectory of the bomb had to be such that it was no longer in the camera's field of view at the time it exploded.

There were two principal modes of operating the shutter so that it opened during the period of the flash bomb burst: by the use of a flash detector (attached to or incorporated in the camera) which was built around a photoelectric cell, and by the use of a timing device synchronized with the timer in the flash bomb. The latter method required such high orders of accuracy, however, that most laboratory and contractor effort in 1956 was concentrated on systems using a photoelectric cell.[108]

In the three or four years following World War II, the Photographic Laboratory at Wright Field developed flash detectors which were designed to open the camera shutter only during the period of peak light intensity from the flash bomb. Since the total time of the flash encompassed about 1/6 of a second, this meant that the camera shutter would be open for about 1/100 of a second to utilize the maximum illumination. By

1949, however, the laboratory was already laying plans for light detectors which would open the camera shutter at the beginning of the bomb explosion and close it only when the light was completely dissipated. The longer exposure time naturally increased the problem of image motion compensation.

World War II flash detectors had generally been aimed directly at the flash bomb burst point, but this practice caused many spurious shutter trips due to searchlights, flak bursts, and ground fires. In consequence, flash detectors came to be operated by light reflected from the ground, although, by 1956 altitudes were becoming so great that reflected light was no longer intense enough to trip camera shutters.[109]

By early 1956, the Aerial Reconnaissance Laboratory was attempting to eliminate known deficiencies in production flash detectors and to design new ones. One flash detector improvement called for amplifying the voltage pulse generated by the bomb burst and increasing the sensitivity of the pickup cell. Photographic engineers believed that the improved detector would trip a camera shutter within five milliseconds of the beginning of the bomb or cartridge burst and thus allow utilization of about 90 percent of the illumination.[110]

The laboratory also studied possible new types of detectors capable of operating at extremely high altitudes, the nature and intensity of ground reflections, and environmental conditions that light detecting equipment would have to endure.[111]

It appeared that the night photography technical requirements of October 1955 could only be met by using the light from several simultaneously detonated flash bombs, so investigations of new bomb initiation methods began. One study concerned a remote bomb initiation system directed from the reconnaissance aircraft itself. The investigation centered about various types of fuzes which reacted to light signals from the control aircraft. The object was to design a fuze that could detonate a salvo of flash bombs simultaneously upon receipt of a single control signal from the aircraft.

A "warning flash device" was nearing completion by the end of June 1956. The warning flash device was a pyrotechnic cartridge ejected from the tail of a photoflash bomb at a predetermined time after the bomb was released from the aircraft. The cartridge would flash and simulaneously detonate several bombs through photocell-actuated fuzes incorporated in each bomb. The flash of the cartridge also served to trip the camera shutter in time to make use of every bit of illumination provided by the bombs.[112]

In addition to working with such articles, the Aerial Reconnaissance Laboratory investigated methods of producing night photographs with little or no artificial illumination at all. Those entrusted with this task were to take note of new high speed lens designs; development of high order, extremely small size illuminants; light amplification systems (wherein the amplified light image was impressed directly on film); and evaluation results of the latest high speed films. Flight tests in early 1956 had already succeeded in obtaining rather low resolution photographs under moonlight alone.[113]

Strike and Gun Cameras

Another field of aerial reconnaissance photography was that of recording the impact of bombs, rockets, and bullets delivered either in air-to-air or air-to-ground attacks. Nearly every aircraft that carried conventional bombs as part of its armament was equipped with a P-2 aerial "strike" camera. This was a fast-cycling (six times per second) still picture camera with shutter speeds up to 1/2000 of a second; it used 100 feet of 70-millimeter film. The P-2 could accommodate six different lens cones, with focal lengths ranging from 1.5 to 12 inches, for bomb damage photography at low, medium, and high altitudes. It weighed only about eight pounds, was extremely compact, and made negatives 2.25 inches square.[114]

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The P-2 was capable of performing direct bomb damage assessment with a reasonable degree of accuracy and clarity. The advent of fantastically powerful nuclear weapons, however, meant that bombardment aircraft no longer could remain directly over the area they were bombing, but had to be many miles from the target at the instant of bomb detonation. Thus, bomb damage assessment could no longer be performed by direct photographic methods, but only by indirect, radiological or electronic means. The P-2 strike camera, therefore, had a very limited future application, if any, and the Aerial Reconnaissance Laboratory planned only to attempt a certain amount of product improvement on the existing article.[115]

The aerial motion picture camera, used almost exclusively in the gun camera configuration for operational missions, was destined to be the subject of much future development work aimed at the recording of air-to-air and air-to-ground rocket firings. The current operational Air Force gun camera was the N-9, a 16-millimeter motion picture camera with a 35-millimeter, f/2.5 lens. The N-9 was capable of operating at altitudes to 50,000 feet, but during clear daylight conditions could record impacts at a maximum distance of only 1,500 feet from the lens. A tremendous amount of research and development work loomed ahead if the 1960 goal of camera operation at 100,000-foot altitudes and at 30,000-foot ranges was to be met.[116]

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Automatic exposure control offered difficult problems. In May 1956, the Aerial Reconnaissance Laboratory concluded flight tests of an automatic exposure control submitted by Specialties, Incorporated, and recommended that the control be incorporated in all N-9 gun cameras. Such an item would substantially improve the exposure of gun camera film and satisfy a long-standing requirement. In 1956 the laboratory was also conducting a two-year study of the over-all automatic exposure control problem, both for air-to-air and air-to-ground strike photography.[117]

Nearly all development work having to do with strike and gun cameras was still in the study stage during the first half of 1956. The requirements for such cameras were so far in advance of the abilities of existing devices that any kind of "product improvement" would fall far short of meeting them. Among the tasks having to do with gun camera development were: a proposed study of ways to improve the quality of strike photography, including the use of thin-base films; component development of new film advancement mechanisms; development of a recoring technique to photograph from beginning to end the complete low altitude bombing system (LABS) maneuver; and a study of materials for use in strike and gun cameras under extreme environmental conditions.[118]

During February 1956 the Night Photo Section of the Aerial Reconnaissance Laboratory proposed a step-by-step development leading to a complete night strike photographic system usable in air-to-air and air-to-ground missions. The first step would be a feasibility study considering an air-fired rocket carrying an illuminator head. Such a rocket would provide illumination and allow identification of a target aircraft or missile, cause temporary blindness for the target aircraft's occupants, bring about low-order destruction in case of direct collisions, and possibly provide illumination sufficient for air-to-ground strike recording.[119]

The extreme requirements for strike cameras not only made the N-9 camera obsolete, but in addition rendered obsolete at least five other aerial motion picture cameras in development. These were the KB-1, KB-2, KB-3, KB-4, and KB-5 cameras, none of which (except possibly the KB-3) would ever become operational because of their limited capabilities. A truly advanced strike camera design would have to await the results of the studies just getting under way.

Airborne Rapid Processing and Unconventional Techniques

Because of the increasingly mobile nature of ground warfare and because of special environmental conditions affecting airborne photographic equipment, the Aerial Reconnaissance Laboratory in 1956 was engaged in an extensive program involving airborne processing magazines and unconventional photographic methods. The principal developments in rapid processing were a magazine utilizing the Polaroid-Land wet process which could produce a positive print in about 60 seconds, and an Ansco magazine that gave promise of turning out dry negatives and positive prints at a rate of one every five seconds. The unconventional techniques being explored for possible use in atomic radiation fields were: the "xerographic" process and two other "photo-electrostatic" methods known commercially as "electrofax" and "kalfax."

The Polaroid-Land magazine had a 9-inch square format and was being engineered to fit most standard 9-by-9-inch aerial cameras. By mid-1956, the laboratory had nearly completed fabrication of an experimental magazine, and future plans called for procurement of a single service test model. 120

In early 1956, the Aerial Reconnaissance Laboratory developed a standard Polaroid-Land camera into a radarscope recorder for use in B-47 aircraft. While such a camera was not strictly a reconnaissance camera, its utilization as a navigation aid showed the versatility of the rapid-processing technique. The camera was installed in a B-47 operating out of Barksdale Air Force Base, Louisiana, and was set to make an exposure of each 360-degree sweep of the navigation system radarscope. This allowed the radar to operate intermittently and thus avoid passive detection and jamming. The prints obtained from the camera were sufficiently clear to allow the B-47 to be navigated by means of photographs alone, prompting the Aerial Reconnaissance Laboratory to recommend the establishment of a requirement for installation of a standard Polaroid-Land camera in B-47 aircraft.[121]

A rapid-processing magazine that offered great promise for future high altitude work was being developed by Ansco Corporation in mid-1956. The laboratory expected delivery of a breadboard model magazine in July, with fabrication of a second model after the first had been flight tested. The Ansco magazine was to have a 9-inch square format and be usable with all standard 9-by-9-inch Air Force cameras. It was designed to develop a dry negative and make one positive print. The positive would be available about five seconds after the first exposure; after that, prints would appear every two seconds. The developed negatives remained in the magazine, while the prints were either ejected from the aircraft for quick pick-up by ground troops or transmitted by facsimile methods to receiving stations within radio range. The design of the complete system was being directed toward operation under the extreme environmental conditions of very high altitude reconnaissance.[122]

Another task, documented but still without a contractor by 30 June 1956, called for a complete rapid processing camera for high altitude reconnaissance. The camera was to develop its own high resolution (50 lines per millimeter) negatives without making positive prints. A fixed-aperture, fixed-focus lens of 12-inch focal length would be designed especially for the camera, as would a very fast focal plane shutter. The camera would give 40 degrees of angular coverage, would require no image motion compensation, and would operate under the high temperatures and low pressures characteristic of high altitude, high speed flight.

The aircraft was to be provided with a special viewer, over which the developed negatives would be carried for immediate interpretation. Television transmission of the negatives to a ground center was also to be provided for in the system design. The camera itself was to be very small in size and light in weight.[123]

In the realm of "unconventional" photographic techniques, the xerographic camera held the ascendency in mid-1956, although other processes were under study. The Haloid Company completed fabrication of an experimental xerographic camera in early 1955, characterizing it as a "prototype for breadboard model cameras," and the Aerial Reconnaissance Laboratory immediately started ground tests. The experimental model was too large and heavy for aerial use, and in addition lacked sensitivity, speed, and simplicity. Ground tests of the camera, however, indicated that the process showed considerable promise since the plates were far less affected by atomic radiation than were standard silver halide photographic materials. The laboratory planned to buy five service test models; one of these was to be bench-tested, two flight tested by Wright Air Development Center, and two flight tested and evaluated by the Tactical Air Command.

The experimental camera produced positive prints 4.5 inches square and had a 12-inch lens cone. Its plates were coated with a selenium-tellurium mixture which was electrostatically charged before an exposure was made. On exposure the plate was discharged, leaving on it an electrical image which was then developed by passing the plate through a cloud of black carbon powder. The image could be transferred to white paper by pressing plate and paper together between rollers, or it could be transmitted by facsimile methods to a ground station. It was also possible to transfer the image from the plate to a clear-base film for viewing or printing in quantity.[124]

Serious faults in the experimental model prompted the laboratory to request establishment of a study task aimed at a design for a truly practical aerial electrostatic camera. The Armour Research Foundation of the Illinois Institute of Technology was granted a study contract in early 1956 to investigate both xerography and a process called "electrofax." The study was to delve into methods of obtaining better resolution through the use of finer grained plates with increased sensitivity, and to investigate thoroughly the problem of atomic radiation effects.

The electrofax process was similar to xerography, but photoconductive material on a paper base was used instead of selenium plates. A great deal of study would be necessary before this process became practicable, since the material was relatively insensitive and hence slow in speed, and its resolution and radiation resistance were unknown.[125]

One other process that had potentialities for aerial photography was "kalfax," a method of developing which gave almost infinite resolution. In this process, unfortunately, the only available photosensitive material was sensitive to ultraviolet radiation but not to visible light. Nevertheless, developing plates by the kalfax process was relatively simple, using either ordinary heat or infrared, and the plates themselves were practically insensitive to atomic radiation. Intensive research into this method promised to be well worth the effort.[126]

Mounts, Controls, and Other Equipment

Camera stabilization became increasingly vital as photographic altitudes increased. Not only did poor stabilization mean poor resolution, but, in the case of area search and mapping photography, a camera that was only a "hair" off vertical produced photographs disoriented by hundreds of feet on the ground. Early efforts in the field of camera stabilization had utilized pendulums as the vertical references, but it was soon discovered that horizontal aircraft accelerations caused sizeable errors in pendulum position. The Air Force then shifted to vertical gyros coupled to geared servo systems. This proved reasonably satisfactory for daytime photography at moderate altitudes, but not for night photography with its longer exposure times. It was the more severe nighttime requirement that led to the development of the torquer mount in which there was no mechanical gearing between the camera gimbal and the airframe.

An even more severe stabilization problem was posed by the requirement for strike photography. During a "normal" reconnaissance mission, the pilot of an aircraft concentrated on flying as straight and level a course as possible, but, during an air-to-air or air-to-ground strike, he frequently had to perform violent maneuvers. To enable the pilot to keep his attention on combat, the strike cameras needed mounts that would automatically maintain a level position during fantastic aircraft gyrations.[127]

As of June 1956, there were several torquer mounts in development, all of which represented an advance over standard geared mounts, but none of which provided the degree of stabilization required by the October 1955 technical requirements. Nearly all the tasks connected with camera stabilization were being performed by a single contractor, Aeroflex Laboratories, Incorporated.

Two torquer mounts, the LS-3, and LS-4, were being developed to accommodate four- and three-camera systems, respectively. The contractor delivered a developmental model of each in June and July 1955, and the Aerial Reconnaissance Laboratory flight tested three 36-inch focal length K-38 cameras in the LS-4 and four 24-inch K-38's in the LS-3. The mounts allowed approximately 20 lines per millimeter resolution from the multi-camera arrangements and provided image motion compensation by swinging the mounts rather than by moving the film. The mounts themselves weighed about 250 pounds each and would fit in an aircraft fuselage 55 inches in diameter. One service test model of each was to be delivered by December 1956.[128]

The LS-6 mount (which was a torquer version of the standard geared A-28 mount) was being engineered to accept nearly all

Air Force cameras currently operational (the K-17C, K-37, K-46, K-47, KA-2, and T-11). This mount would actually be the only standardized Air Force torquer mount since most of the other developmental mounts were tailored for a particular aircraft. The LS-6, weighing about 150 pounds, permitted resolution on the order of 20 lines per millimeter. As in the case of the LS-3 and LS-4 mounts, December 1956 was the forecast date for delivery of three LS-6 service test models. 129

Aeroflex Laboratories was also developing a general purpose mount for damage assessment photography during raids with conventional bombs. This was the A-32 mount, a service test model of which the Aerial Reconnaissance Laboratory had put through environmental tests by June 1956. This mount could be installed in any bomber type aircraft having a vertical camera well, and could accommodate most standard Air Force cameras. It provided excellent vibration isolation for the cameras, and had a remote pitch control permitting the pitch angle to be varied from eight degrees forward to 40 degrees rearward. The complete mount assembly, including control box and cable, weighed about 48 pounds. The Aerial Reconnaissance Laboratory expected delivery of nine more service test models complete with controls in July 1956, at which time further tests would be undertaken by Wright Air Development Center, Air Proving Ground Command, and Strategic Air Command. 130

The laboratory had selected no contractor to develop a planned miniaturized torquer mount system capable of fully guaranteeing high acuity in a small reconnaissance camera. The goal of development was to be a mount that would operate with maximum efficiency in spite of its small size.[131]

While most of these Air Force torquer mounts neared the end of the development stage, the Aerial Reconnaissance Laboratory still faced the problem of satisfying the technical requirements issued by the Air Research and Development Command in October 1955. As a start, the laboratory planned a study of all possible mounting techniques for high acuity cameras. Since movement of the photographic image during exposure was still the largest single cause of loss of resolution, this task would be of special importance for some time to come.

Aeroflex Laboratories was performing both study and component development in the entire field of stabilization and mounting. Any improvements or important discoveries were to be carried into equipment development. The investigation included such areas as low inertia mount systems, "drift" of mount gyroscopes, low frequency vibration isolators, environmental protection of mount components, camera center of gravity, and image motion compensation by "swinging" techniques.[132]

Aeroflex was also developing specific components needed for satisfaction of the high altitude area and mapping reconnaissance requirements. One assignment was to develop lightweight systems for determining true vertical during and after "moderate" aircraft maneuvers and to investigate methods whereby such a system could be tied into an inertial autonavigator. The contractor was building ten service test systems in early 1956; these were to be engineered for use with the LS-6 torquer mount.[133] The vertical computing system would become unnecessary if one of more cameras could be "slaved" to a central reference such as an inertial navigation system. This was to be done through the use of two matched pendulums. Experimental equipment of this type was deliverd to the Aerial Reconnaissance Laboratory in October 1955.[134]

Aeroflex was also developing an extremely sensitive gyroscopic steadying unit for use in very high acuity camera mount systems. Not only was the unit to be fast acting and immune to interference, but it was also to operate effectively during moderate combat maneuvers. Two experimental units were being fabricated by early 1956, as was an especially sensitive control.[135]

The contractor was responsible for another task (suspended during the first half of 1956 because of the lack of suitable test facilities), which demanded investigation of rocket strike recording techniques. No limitation on aircraft maneuvers after firing of the rockets was to be allowed; the camera mount was to have freedom to move 78 degrees in pitch and 30 degrees in roll. As if these performance parameters were not extreme enough, the mount itself could weigh only about 18 pounds![136]

Another development involving pendulums instead of gyroscopes for the steadying reference in camera mount systems was assigned by Aerial Reconnaissance Laboratory to the Bill Jack Scientific Instrument Company. The contractor was to investigate "long period" pendulums as possible substitutes for gyroscopic mount systems. If a pendulum proved satisfactory, considerable savings in mount weight and size could be provided. During the first half of 1956, the contractor delivered to Wright Field a breadboard model of a pendulum having a period of one minute. Testing was under way at the end of June.[137]

After World War II, recognition of the need for more accurate--and more complicated--aircraft camera controls led to the unification of scattered and uncoordinated efforts hitherto characteristic of the camera control field. This led to the development of the "universal camera control system," a series of about 45 "packages" which computed exposure data of all types and fed correct settings into aerial cameras.

The system, as first developed, was quite bulky and heavy, but was nevertheless considerably smaller and lighter than it would have been without the unifying influence of the control task.

Improvements in various parts of the system followed. To reduce over-all size, a "miniaturized" control system was designed and by early 1955 had been assembled. Methods of further reducing the bulk of the system were under study during the first half of 1956.[138] Specific components of the universal camera control system included intervalometers, automatic focusing devices, power supplies, control panels, and ground speed and altitude measuring devices.[139]

A problem that had always been difficult and time consuming for aerial photographers, processers, and photo interpreters alike was that of recording data on negatives. Originally, each negative on a film strip was automatically numbered in flight by a device in the camera, and then further information was taken from the pilot's or observer's flight log and hand lettered on the negative by ground processers. Later, visual presentations of altitude, time, exposure number, and other data were automatically registered along one edge of each negative. Space for these visual presentations was limited, however, and as further data were required, such as latitude, longitude, aircraft heading, ground speed, and sortie number, the visual method gave way to various systems of coded dots which could cram large amounts of information into a very small space.

The most elaborate and versatile coded data recording system in development was one delivered to Wright Field in December 1955 by the Federal Telecommunications Laboratories. The system impressed a series of small dots on each negative as it was exposed in flight. These dots, when translated by suitable electronic equipment could give the negative number, camera position, focal length, squadron number, sortie number, date, time zone, and time to the nearest tenth of a second. Furthermore, data taken from the aircraft's navigation equipment could be included in the coded presentation--latitude north and south, longitude east and west to the nearest tenth of a minute, pitch, roll, and drift angles, true course, and ground speed. From the aircraft's radar altimeter, accurate measurement of altitude above the terrain also was recorded.

The coded dots were impressed on the negative through the medium of a one-inch cathode ray tube that operated automatically. The system which weighed 75 pounds, was designed to operate with 70-millimeter film like that used in the KA-5 and P-2 cameras. The coded information could, in addition to being recorded on the negative, be recorded on magnetic tape where it could be translated by telemetry circuits.

The ground-based portion of the equipment consisted of a film reader and automatic titler. This machine could translate the coded information on each negative and type it out in letters and numbers on the negative in gold leaf ink. The translated information could also be used to punch tapes and cards for use in digital computers and other digital data reduction equipment. As if this were not enough, the reader was capable of producing on a cathode ray tube a readable display of the coded information so film could be scanned before being titled. A video output of the picture being scanned, compatible with television networks in the United States, was furnished for good measure.[140]

Aerial Reconnaissance Studies

Because the photographic requirements of the 1960-1970 period were so advanced, the Aerial Reconnaissance Laboratory during 1956 undertook several studies covering every phase of the aerial reconnaissance process. Means of increasing acuity and reducing size of camera systems were being exhaustively investigated, as were operational procedures for increasing the information content of photographic missions. Fine grain films and thin base films were to receive their share of research emphasis, and lenses and photographic "windows" were the subject of much intensive research and development work. To increase reliability and ease of maintenance of photographic equipment, "test equipment techniques" were also to be studied.[141]

One entire project, which had been in existence since 1949, was devoted entirely to "blue sky" research in the photographic reconnaissance field. The work connected with the project was conducted almost entirely by the Physical Research Laboratory of Boston University, although some effort was subcontracted to other research institutions. In general, the studies to be conducted during the 1956-1960 period were concerned with long range oblique photography, problems of photographic reconnaissance at altitudes of 200,000 feet and more, low altitude navigation and reconnaissance, combat photography, data transmission, night reconnaissance without artificial illuminants, radarscope recording, factors influencing the quality of aerial photographs, and compilation of all current knowledge in the field.

The project was founded on the assumption that any aerial photographic reconnaissance system was made up of four elements: airborne collection, physical processing or reduction, analysis and interpretation, and data presentation and dissemination. When the military problem (collecting usable data about the enemy under conditions usually far less than ideal) was added to the system analysis, requirements for research and development immediately stood out. As these requirements emerged, the Boston laboratory set up tasks to meet them.[142]

Among the study tasks being conducted under this project were: theoretical investigations of low altitude reconnaissance systems; studies of air turbulence and haze and their effects on photographic image quality; experiments on the effects of thermal shock on photographic windows; determination of criteria for detecting detail on aerial photographic prints; and the establishment of suitable examinations to separate likely from unlikely candidates for the job of photo interpreter.[143]

Other tasks that included some component development work were: a search for so unconventional a thing as a "photosensitive micro-organism" to be used on film instead of standard emulsions such as silver halide; fabrication of laboratory "electro-optical" and thermal reconnaissance devices; experiments with machine tools to obtain better surfaces on optical components; work with "non-mechanical" shutters and focusing devices; and the building of long focal length mirror optical systems for aerial reconnaissance.[144]

[redacted]

As of 30 June 1956, the Aerial Reconnaissance Laboratory had reoriented its efforts in the photographic field toward meeting the requirements laid down in the October 1955 technical documents from Balitmore. With several "breakthroughs" already to its credit, the laboratory was confident that the requirements would be met.

Notes, Chapter VII

1. Presn., Lt. Col. H. W. Pote, Trends in Photo Intelligence, Oct. 1949, in Public Information Branch (hereafter cited as P.I. Br.), Office of Information Services (hereafter cited as O.I.S.), files.

2. Article, Col. G. W. Goddard, Ch., Photo. Lab., Eng. Div., AMC, "New Developments for Aerial Reconnaissance," in Photogrammetric Engineering, Mar. 1949, in P.I. Br., O.I.S., files; Research and Development Board Project Card (hereafter cited as DD Form 613), Proj. 6211, Day Reconnaissance and Mapping Cameras, 26 May 1954, in Projects Control Br. (hereafter cited as PCB), DCS/R&D, files.

3. Pote presn., Oct. 1949.

4. Goddard art., Mar. 1949.

5. ARDC Technical Program Planning Document (hereafter cited as ARDC TPPD), Aug. 1955 revision, subj.: Photography, see Doc. VII-34.

6. ARDC Technical Requirement (hereafter cited as ARDC TR) No. 95-55, 24 Oct. 1955, subj.: Aerial Photo Intelligence, see Doc. VII-37.

7. ARDC TPPD, Aug. 1955 Rev., see Doc. VII-34.

8. Ibid., see Doc. VII-34; DD Form 613, Proj. 6211, 26 May 1954.

9. ARDC TPPD, Aug. 1955 Rev., see Doc. VII-34.

10. DD Form 613, Proj. 6211, 26 May 1954; rpt., "The Ultra High Altitude Reconnaissance Camera," undated, by V. K. Yenner, Recon. Camera Sect., Photo. Recon. Br., Aerial Recon. Lab. (hereafter cited as ARL), Dir/Dev., WADC, see Doc. VII-40.

11. Yenner rpt., see Doc. VII-40.

12. ARDC TPPD, Aug. 1955 revision, see Doc. VII-34; presn. by ARL on Northeast Air Command and Alaskan Air Command day, 14 Dec. 1955, notes in Hist. Br. files.

13. ARDC TPPD, Aug. 1955 revision, see Doc. VII-34.

14. Presn. by ARL on I. G. Presn. Day, 20 July 1955; presn. by ARL on USAF Presn. Day, 4 Oct. 1955, both in Hist. Br. files.

15. Goddard art., Mar. 1949.

16. Handbook of Photographic Equipment (hereafter cited as T.O. 10-1-2), 15 June 1955, Sect. II. pp. 2&3, see Doc. VII-13 & VII-14.

17. Photo Capability of the RB-36, 30 June 1956, compiled by J. King, Hist. Br., see Doc. VII-2.

18. Photo Capability of the RF-84F, 30 June 1956, compiled by J. King, Hist. Br., See Doc. VII-7.

19. T.O. 10-1-2, 15 June 1955, Sect. II, p. 7, see Doc. VII-15.

20. Photo Capability of the RB-36, 30 June 1956, see Doc. VII-2.

21. Photo Capability of the RF-84F, 30 June 1956, see Doc. VII-7.

22. Equipment Data Sheet (hereafter cited as DS) No. 40, 25 Aug. 1954, prep. by ARL, see Doc. VII-22.

23. DD Form 613, Proj. 6211, Task 62128, 5 Apr. 1956, in PCB, DCS/P&O files; DD Form 613, Proj. 6216, Task 62015, 12 Mar. 1956, see Doc. VII-42.

24. Photo Capability of the RF-101, 30 June 1956, compiled by J. King, Hist. Br., see Doc. VII-8; table, Reconnaissance Cameras--Current Operational Functions, compiled by J. King, Hist. Br., see Doc. VII-11.

25. Photo Capability of the RF-105, 30 June 1956, compiled by J. King, Hist. Br., see Doc. VII-10.

26. Photo Capability of the RF-104, 30 June 1956, compiled by J. King, Hist. Br., see Doc. VII-9.

27. Photo Capability of the RB-52, 30 June 1956, compiled by J. King, Hist. Br., see Doc. VII-4.

28. T.O. 10-1-2, 15 June 1955, Sect. II, p. 22, see Doc. VII-30.

29. Photo Capability of the RB-66, 30 June 1956, compiled by J. King, Hist. Br., see Doc. VII-6; Photo Capability of the RF-105, 30 June 1956, see Doc. VII-10.

30. T.O. 10-1-2, 15 June 1955, Sect. II, p. 13 see Doc. VII-18.

31. DD Form 613, Proj. 6216, Task 62134, 12 Mar. 1956, see Doc. VII-42; DD Form 613, Proj. 6211, Task 62128, 2 June 1955, see Doc. VII-33.

32. Photo Capability of the RB-66, 30 June 1956, see Doc. VII-6.

33. Photo Capability of the RF-105, 30 June 1956, see Doc. VII-10; DD Form 613, Proj. 6211, Task 62128, 2 June 1955, see Doc. VII-33; DS No. 3, 25 Aug. 1954, see Doc. VII-21.

34. T.O. 10-1-2, 15 June 1955, see Docs. VII-13, -14, -15, -16, -17, -18, -19, and -30.

35. Table, Reconnaissance Cameras--Current Operational Functions, 30 June 1956, see Doc. VII-11.

36. Goddard art., Mar. 1949.

37. ARDC R&D Task Plan (hereafter cited as ARDC Form 98), Proj. 6214, Task 62043, 2 July 1953, in Recon. Camera Sect., Photo. Recon. Br., ARL, files; ARDC R&D Mgmt. Rpt. (hereafter cited as ARDC Form 111), Proj. 6214, Task 62043, 13 May 1955, see Doc. VII-32; ARDC Service Test Requirement (hereafter cited as ARDC Form 171), Proj. 6214, Task 62043, 3 Jan. 1956, in Recon. Camera Sect., Photo. Recon. Br., ARL, files.

38. ARDC Form 111, Proj. 6214, Task 62043, 12 Apr. 1956, in PCB, DCS/P&O, files.

39. Ltr., Vectron, Inc., to CG, AMC. 28 May 1956, subj.: Progress Report No. 34 (E-2 Panoramic Camera), in Recon. Camera Sect., Photo. Recon. Br., ARL, files.

40. DD Form 613, Proj. 6213, Task 62008, 18 Oct. 1955, see Doc. VII-36; interview, R. A. Strasser, Asst. Ch., Photo. Recon. Br., ARL, 9 Aug. 1956, by J. King, Hist. Br. (hereafter cited as Strasser interview).

41. ARDC Form 98, Proj. 6211, Task 62077, 26 May 1953, in Recon. Camera Sect., Photo. Recon. Br., ARL, files; ARDC Form 111, Proj. 6211, Task 62077, 4 Mar. 1955, see Doc. VII-31; ARDC Form 111, Proj. 6211, Task 62077, 20 Sept. 1955, in PCB DCS/P&O, files; ARDC Form 111, Proj. 6211, Task 62077, 20 Jan. 1956, in PCB, DCS/P&O, files.

42. DS No. 12, 25 Aug. 1954, see Doc. VII-26.

43. ARDC Form 98, Proj. 6211, Task 62078, 2 Dec. 1952, in Recon. Camera Sect., Photo. Recon. Br., ARL, files; ARDC Form 111, Proj. 6211, Task 62078, 20 Sept., 1955, in PCB, DCS/P&O, files; ARDC Form 111, Proj. 6211, Task 62078, 5 Apr. 1956, in PCB, DCS/P&O, files.

44. ARDC Form 111, Proj. 6211, Task 62078, 20 Jan. 1956, in PCB, DCS/P&O, files; DS No. 4, 25 Aug. 1954, see Doc. VII-29.

45. Status of USAF Equipment, Request for Type Classification (hereafter cited as ARDC Form 81), Proj. 6279, Task 62685, 21 June 1956, in Recon. Camera Sect., Photo. Recon. Br., ARL, files.

46. ARDC Form 111, Proj. 6214, Task 62637, 12 Apr. 1956, in PCB, DCS/P&O, files.

47. Table, Reconnaissance Cameras--Current Operational Functions, 30 June 1956, see Doc. VII-11; Pote presn., Oct. 1949.

48. Photo Capability of the RB-36, 30 June 1956, see Doc. VII-2.

49. Photo Capability of the RF-84F, 30 June 1956, see Doc. VII-7.

50. Photo Capability of the RB-36, 30 June 1956, see Doc. VII-2.

51. Photo Capability of the RB-47, 30 June 1956, compiled by J. King, Hist. Br., see Doc. VII-3; Photo Capability of the RF-84F, 30 June 1956, see Doc. VII-7.

52. Photo Capability of the RB-52, 30 June 1956, see Doc. VII-4; Photo Capability of the RB-57, 30 June 1956, compiled by J. King, Hist. Br., see Doc. VII-5.

53. Photo Capability of the RF-101, 30 June 1956, see Doc. VII-8; Photo Capability of the RF-104, 30 June 1956, see Doc. VII-9; Photo Capability of the RF-105, 30 June 1956, see Doc. VII-10.

54. Photo Capability of the RF-105, 30 June 1956, see Doc. VII-10.

55. DS Nos. 4, 17, and 41, 25 Aug. 1954, see Docs. VII-29, -25, & -27; ARDC Form 81, Proj. 6279, Task 62685, 21 June 1956, in Recon. Camera Sect., Photo. Recon. Br., ARL, files.

56. Strasser interview, 9 Aug. 1956.

57. DD Form 613, Proj. 6211, Task 62006, 2 June 1955, see Doc. VII-33; ARDC Form 111, Proj. 6211, Task 62006, 20 Jan. 1956, in PCB, DCS/P&O, files.

58. DS No. 41, 25 Aug. 1954, see Doc. VII-27.

59. ARDC Form 81, Proj. 6279, Task 62685, 21 June 1956, in Recon. Camera Sect., Photo. Recon. Br., ARL, files.

60. ARDC Form 111. Proj. 6211, Task 62631, 6 Mar. 1956, see Doc. VII-41.

61. ARDC Form 111, Proj. 6273, Task 62617, 15 Mar. 1956, see Doc. VII-45.

62. ARDC Form 111, Proj. 6273, Task 62622, 15 Mar. 1956, see Doc. VII-45.

63. ARDC Form 111, Proj. 6273, Task 62619, 15 Mar. 1956, see Doc. VII-45.

64. Photo Capability of the RB-36, 30 June 1956, see Doc. VII-2; Photo Capability of the RF-84F, see Doc. VII-7.

65. Photo Capability of the RB-66, 30 June 1956, see Doc. VII-6; Photo Capability of the RB-52, 30 June 1956, see Doc. VII-4; Photo Capability of the RF-105, 30 June 1956, see Doc. VII-10; Photo Capability of the RF-104, 30 June 1956, see Doc. VII-9; Photo Capability of the RF-101, 30 June 1956, see Doc. VII-8.

66. DS No. 41, 25 Aug. 1954, see Doc. VII-27; DS No. 4, 25 Aug. 1954, see Doc. VII-29.

67. DS No. 2, 25 Aug. 1954, see Doc. VII-24.

68. DD Form 613, Proj. 6213, Task 62038, 18 Oct. 1955, see Doc. VII-36.

69. Presn., Col. G. W. Goddard, Ch., Photo. Lab., Eng. Div., AMC, "Photo Reconnaissance Must be Ready Ahead of Time," 1951, (hereafter cited as Goddard presn.), in P.I.Br., O.I.S., files.

70. Table, Reconnaissance Cameras--Current Operational Functions, 30 June 1956, see Doc. VII-11.

71. *Ibid.*, see Doc. VII-11.

72. *Ibid.*, see Doc. VII-11.

73. DS No. 53, 25 Aug. 1954, see Doc. VII-23.

74. DS No. 2, 25 Aug. 1954, see Doc. VII-24.

75. DS No. 17, 25 Aug. 1954, see Doc. VII-25; Strasser interview, 9 Aug. 1956.

76. DS Nos. 41, and 4, 25 Aug. 1954, see Docs. VII-27 & VII-29; ARDC Form 81, Proj. 6279, Task 62685, 21 June 1956, in Recon. Camera Sect., Photo Recon. Br., ARL, files.

77. ARDC Form 81, Proj. 6279, Task 62685, 21 June 1956, in Recon. Camera Sect., Photo. Recon. Br., ARL, files.

78. DS No. 38, 25 Aug. 1954, see Doc. VII-28; DD Form 613, Proj. 6213, Task 62372, KA-16, 18 Oct. 1955, see Doc. VII-36.

79. ARDC TPPD, Aug. 1955 Rev., see Doc. VII-34.

80. ARDC TR No. 96-55, 24 Oct. 1955, subj.: Map, Chart and Model Production, see Doc. VII-38.

81. ARL Program Reference Books.

82. Table, Reconnaissance Cameras→Current Operational Functions, 30 June 1956, see Doc. VII-11.

83. DS No. 24, 25 Aug. 1954, in Hist. Br. Files.

84. Presn. by ARL on MATS Presn. Day, 1 Mar. 1955, in Hist. Br. files; DF, E. D. Sewall, Ch. Aerial Photo. Br., Engr. R&D Labs. (Corps of Engineers), W-PAFB, to Ch., Recon. Camera Sect., Photo. Recon. Br., ARL, Dir/Dev., WADC, 9 Dec. 1955, subj.: Convergent Camera, in Recon. Camera Sect., Photo. Recon. Br., ARL, files; ltr., F. L. Holloway, Tech. Dir., ARL, to Cmdr., ARDC, 30 Apr. 1956, subj.: Convergent Mapping Photography, in Recon. Camera Sect., Photo. Recon. Br., ARL, files.

85. ARDC Form 111, Proj. 6211, Task 62640, 20 Jan. 1956; DD Form 613, Proj. 6211, Task 62640, 5 Apr. 1956, both in PCB, DCS/P&O, files.

86. DF, V. K. Yenner, Ch., Recon. Camera Sect., Photo. Recon. Br., ARL, Dir/Dev., WADC, to Communication and Photo. Br., Aero. Equip. Div., AMC, 19 July 1956, subj.: Product Improvement Program for KC-1 Mapping Camera, in Recon. Camera Sect., Photo. Recon. Br., ARL, files.

87. ARDC TR No. 95-55, 24 Oct. 1955, see Doc. VII-37; ARDC TPPD, Aug. 1955 Rev., see Doc. VII-34; DD Form 613, Proj. 6212, 3 June 1955, in PCB, DCS/P&O, files.

88. DD Form 613, Proj. 6212, 3 June 1955, in PCB, DCS/P&O, files.

89. ARDC Form 111, Proj. 6212, Task 62024, 6 May 1955, in PCB, DCS/P&O, files; table, Reconnaissance Cameras--Current Operational Functions, 30 June 1956, see Doc. VII-11.

90. Photo Capability of the RB-52, 30 June 1956, see Doc. VII-4.

91. T.O. 10-1-2, 15 June 1955, Sect. II, p. 11, see Doc. VII-16.

92. Table, Reconnaissance Cameras--Current Operational Functions, 30 June 1956, see Doc. VII-11.

93. T.O. 10-1-2, 15 June 1955, Sect. II, p. 12, see Doc. VII-17; DD Form 613, Proj. 6216, Task 62015, 12 Mar. 1956, see Doc. VII-42.

94. DS No. 54, 25 Aug. 1954, see Doc. VII-20; DD Form 613, Proj. 6216, Task 62015, 12 Mar. 1956, see Doc. VII-42.

95. ARDC Form 111, Proj. 6212, Task 62034, 22 Oct. 1954; ARDC Form 111, Proj. 6212, Task 62034, 5 Jan. 1956, both in PCB, DCS/P&O, files.

96. ARDC Form 111, Proj. 6212, Task 62529, 4 Mar. 1955; ARDC Form 171, Proj. 6212, Task 62529, 3 Jan. 1956, both in PCB, DCS/P&O, files.

97. ARDC Form 111, Proj. 6212, Task 62529, 20 Jan. 1956; DD Form 613, Proj. 6212, Task 62529, 5 Apr. 1956, both in PCB, DCS/P&O, files.

98. Goddard presn., 1951; table, Reconnaissance Cameras--Current Operational Functions, 30 June 1956, see Doc. VII-11.

99. Photo Capability of the RB-47, 30 June 1956, see Doc. VII-3; Photo Capability of the RB-57, 30 June 1956, see Doc. VII-5; Photo Capability of the RF-84F, 30 June 1956, see Doc. VII-7.

100. Photo Capability of the RB-57, 30 June 1956, see Doc. VII-5; Photo Capability of the RB-66, 30 June 1956, see Doc. VII-6; Photo Capability of the RF-101, 30 June 1956, see Doc. VII-8.

101. T.O. 10-1-2, 15 June 1955, Sect. II, p. 14, see Doc. VII-19.

102. ARDC Form 111, Proj. 6212, Task 62635, 20 Jan. 1956, in PCB, DCS/P&O, files; DD Form 613, Proj. 6212, Task 62635, 31 July 1956, see Doc. VII-47; ARDC Form 111 Proj. 6273, Task 62443, 15 Mar. 1956, see Doc. VII-45; ARDC Form 111, Proj. 6273, Task 62629, 15 Mar. 1956, See Doc. VII-45.

103. Goddard art., March 1949; WADC Weekly Technical Information Report (hereafter cited as WADC WTIR), 2 Mar. 1956, pp. 12-13, in Hist. Br. files; DD Form 613, Proj. 6218, 3 June 1955, in PCB, DCS/P&O, files.

104. ARDC Form 111, Proj. 6218, Tasks 62087, 62454, and 62639, 20 Jan. 1956, in PCB, DCS/P&O, files; ARDC Form 111, Proj. 6218, Task 62639, 2 Apr. 1956, see Doc. VII-46.

105. ARDC Form 111, Proj. 6218, Task 62532, 20 Jan. 1956, in PCB, DCS/P&O, files.

106. Goddard art., Mar. 1949; ARDC Form 111, Proj. 6218, Task 62457, 20 Jan. 1956, in PCB, DCS/P&O, files.

107. ARDC Form 111, Proj. 6218, Task 62457, 20 Jan. 1956, in PCB, DCS/P&O, files; WADC WTIR, 17 Feb. 1956, p. 20; WADC WTIR, 27 Apr. 1956, p. 16; WADC WTIR, 1 June 1956, p. 19.

108. Goddard art., Mar. 1949; DD Form 613, Proj. 6212, 3 June 1955, in PCB, DCS/P&O, files.

109. Goddard art., Mar. 1949; WADC WTIR, 24 Feb. 1956, p. 13, in Hist. Br. files.

110. WADC WTIR, 24 Feb. 1956, p. 13; WADC WTIR, 20 Jan. 1956, p. 2.

111. ARDC Form 111, Proj. 6217, Tasks 62053, and 62054, 20 Jan. 1956, in PCB, DCS/P&O, files.

112. ARDC Form 111, Proj. 6218, Tasks 62081, and 62533, 20 Jan. 1956, in PCB, DCS/P&O, files.

113. ARDC Form 111, Proj. 6218, Task 62534, 12 Mar. 1956, see Doc. VII-43.

114. T.O. 10-1-2, 15 June 1955, Sect. V, p. 231, in Ch., ARL, files.

115. WADC WTIR, 6 Apr. 1956, pp. 11-12.

116. T.O. 10-1-2, 15 June 1955, Sect. V, p. 210, in Ch., ARL, files; TR 99-55, 24 Oct. 1955, see Doc. VII-39; ARL Program Reference Books.

117. WADC WTIR, 18 May 1956, p. 19; ARDC Form 111, Proj. 6281, Task 62463, 13 Mar. 1956, see Doc. VII-44.

118. DD Form 613, Proj. 6220, Task 62526, 14 Mar. 1956, in PCB, DCS/P&O, files; WADC WTIR, 2 Mar. 1956, p. 11; ARDC Form 111, Proj. 6281, Tasks 62444, 62651, and 62652, 20 Jan. 1956, all in PCB, DCS/P&O, files; ARDC TR No. 99-55, 24 Oct. 1955, see Doc. VII-39.

119. WADC WTIR, 17 Feb. 1956, pp. 17-18.

120. WADC WTIR, 18 May 1956, pp. 17-18; ARDC Form 111, Proj. 6214, Task 62074, 12 Apr. 1956, in PCB, DCS/P&O, files.

121. WADC WTIR, 16 Mar. 1956, pp. 9-12.

122. ARDC Form 111, Proj. 6214, Task 62486, 2 Apr. 1956, in Recon. Camera Sect., Photo. Recon. Br., ARL, files; ARDC Form 111, Proj. 6214, Task 62486, 12 Apr. 1956, in PCB, DCS/P&O, files; Activity Rpt., ARL, Proj. 6214, Task 62486, undated, in Recon. Camera Sect., Photo. Recon. Br., ARL, files.

123. ARDC Form 111, Proj. 6214, Task 62636, 12 Apr. 1956, in PCB, DCS/P&O, files.

124. ARDC Form 111, Proj. 6214, Task 62075, 13 May 1955, see Doc. VII-32; ARDC Form 171, Proj. 6214, Task 62075, 3 Jan. 1956; WADC WTIR, 17 Feb. 1956, pp. 25-26; ARDC Form 111, Proj. 6214, Task 62075, 12 Apr. 1956, in PCB, DCS/P&O, files.

125. ARDC Form 171, Proj. 6214, Task 62075, 3 Jan. 1956, in Recon. Camera Sect., Photo. Recon. Br., ARL, files; ARL Program Reference Books; ARDC Form 111, Proj. 6272, Task 62175, 12 Mar. 1956, in PCB, DCS/P&O, files.

126. ARDC Form 111, Proj. 6272, Task 62172, 12 Mar. 1956, in PCB, DCS/P&O, files; ARL Program Reference Books.

127. DD Form 613, Proj. 6216, 11 Mar. 1956, in PCB, DCS/P&O, files; DD Form 613, Proj. 6216, 12 Mar. 1956, see Doc. VII-42.

128. DD Form 613, Proj. 6216, Task 62134, 11 Mar. 1956, in PCB, DCS/P&O, files.

129. DD Form 613, Proj. 6216, Task 62015, 11 Mar. 1956, in PCB, DCS/P&O, files.

130. DD Form 613, Proj. 6216, Task 62039, 11 Mar. 1956, in PCB, DCS/P&O, files; WADC WTIR, 1 June 1956, p. 17.

131. DD Form 613, Proj. 6216, Task 62017, 12 Mar. 1956, see Doc. VII-42.

132. DD Form 613, Proj. 6216, Task 62645, 11 Mar. 1956, in PCB, DCS/P&O, files; DD Form 613, Proj. 6216, Task 62178, 12 Mar. 1956, see Doc. VII-42.

133. DD Form 613, Proj. 6216, Task 62010, 12 Mar. 1956, see Doc. VII-42.

134. DD Form 613, Proj. 6216, Task 62014, 12 Mar. 1956, see Doc. VII-42.

135. DD Form 613, Proj. 6216, Task 62016, 12 Mar. 1956, see Doc. VII-42.

136. DD Form 613, Proj. 6216, Task 62041, 11 Mar. 1956, in PCB, DCS/P&O, files.

137. DD Form 613, Proj. 6216, Task 62368, 11 Mar. 1956, in PCB, DCS/P&O, files.

138. DD Form 613, Proj. 6217, Tasks 62050, and 62414, 12 Apr. 1955, in PCB, DCS/P&O, files.

139. ARDC Form 111, Proj. 6217, Tasks 62051, 62068, and 62453, 20 Jan. 1956, in PCB, DCS/P&O, files; WADC WTIR, 9 Mar. 1956, pp. 10-11; WADC WTIR, 1 June 1956, p. 16.

140. ARDC Form 111, Proj. 6284, Task 62371, 14 Mar. 1956, in PCB, DCS/P&O, files.

141. ARDC Form 111, Proj. 6214, Task 62638, 12 Apr. 1956, in PCB, DCS/P&O, files; DD Form 613, Proj. 6220, 14 Mar. 1956, in PCB, DCS/P&O, files; DD Form 613, Proj. 6220, Tasks 62632, and 62525, 14 Mar. 1956, in PCB, DCS/P&O, files; ARDC Form 111, Proj. 6273, 15 Mar. 1956, see Doc. VII-45; ARDC Form 111, Proj. 6273, Task 62180, 15 Mar. 1956, see Doc VII-45; ARDC Form 111, Proj. 6295, 11 May 1956, in PCB, DCS/P&O, files.

142. DD Form 613, Proj. 6291, 2 June 1954, in PCB, DCS/P&O, files; ARDC Form 111, Proj. 6291, 2 Mar. 1955, in Hist. Br. files.

143. ARDC Form 111, Proj. 6291, Tasks 62467, 62468, 62469, 62470, 62478, 10 Oct. 1955, see Doc. VII-35.

144. ARDC Form 111, Proj. 6291, Tasks 62471, 62472, 62473, 62474, and 62476, 10 Oct. 1955, see Doc. VII-35.